



MFOP-FA-EMI-30X Rough Draft4

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

MSFC EMI Test Facility (METF)

EMI/EMC Facility Operating Procedure For MIL-STD-461E

**Environments Group
Engineering Systems Department
ED44**

VERIFY THAT THIS IS THE LATEST VERSION BEFORE USE

| | | |
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| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
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DOCUMENT HISTORY LOG

| Status (Baseline/ Revision/ Canceled) | Document Revision | Effective Date | Description |
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| ROUGH DRAFT 2 | | 9/26/2003 | Added EUT Test Preparation Sheets and METF Test Equipment Calibration Lists in Section 4. Modified CE101 and RE102 sections. |
| ROUGH DRAFT 3 | | 3/11/2004 | Added RS103. Modified test equipment tables for positive and return lead LISNs and test software. |
| ROUGH DRAFT 4 | | 8/24/04 | Updated METF Test Equipment Calibration Lists in Section 4. |

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1. INTRODUCTION

1.1 Purpose.

This procedure establishes the requirements and test operations necessary to prepare and operate the MSFC EMI Test Facility (METF), and to perform MIL-STD-461E testing in support of EMI qualification and development testing as defined by Customer Agreement, MSFC Forms 4404 submitted by appropriate test requestors.

1.2 Responsibilities.

The operation of this facility and the performance of the operating procedure shall be conducted or coordinated by the assigned personnel of the Marshall Space Flight Center, Engineering Directorate, Engineering Systems Department, Environments Group, Electromagnetic Environmental Effects (E3) Team, ED44.

It shall be the responsibility of the customer test requestors to define EMI/EMC requirements and services desired and to submit these using MSFC Form 4404, EMI Test Customer Agreement Form. MSFC Form 4404 is found in Appendix A.

1.3 Emission and susceptibility designations.

The emissions and susceptibility and associated test procedure requirements in this standard are designated in accordance with an alphanumeric coding system. Each requirement is identified by a two-letter combination followed by a three digit number. The number is for reference purposes only. The meaning of the individual letters is as follows:

C = Conducted
R = Radiated
E = Emission
S = Susceptibility

- a. Conducted emissions requirements are designated by "CE---."
- b. Radiated emissions requirements are designated by "RE---."
- c. Conducted susceptibility requirements are designated by "CS---."
- d. Radiated susceptibility requirements are designated by "RS---."
- e. "---" = numerical order of requirement from 101 to 199.

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2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Government documents, drawings, and publications.

The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

DEPARTMENT OF DEFENSE (DoD)

- | | | |
|--------------|---|---|
| DoDI 6055.11 | - | Protection of DoD Personnel from Exposure to Radio Frequency Radiation and Military Exempt Lasers |
| SD-2 | - | Buying Commercial and Nondevelopmental Items |

NORTH ATLANTIC TREATY ORGANIZATION

- | | | |
|-------------|---|---|
| STANAG 3516 | - | Electromagnetic Interference and Test Methods for Aircraft Electrical and Electronic Equipment |
| STANAG 4435 | - | Electromagnetic Compatibility Testing Procedures and Requirements for Naval Electrical and Electronic Equipment (Surface Ship, Metallic Hull) |
| STANAG 4436 | - | Electromagnetic Compatibility Testing Procedures and Requirements for Naval Electrical and Electronic Equipment (Surface Ship, Non-Metallic Hull) |
| STANAG 4437 | - | Electromagnetic Compatibility Testing Procedures and Requirements for Naval Electrical and Electronic Equipment (Submarines) |

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2.2 Non-Government publications.

The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DoDISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DoDISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

- ANSI/IEEE C63.2 - Standard for Instrumentation-Electromagnetic Noise and Field Strength, 10 kHz to 40 GHz, Specifications
- ANSI/IEEE C63.4 - Standard for Electromagnetic Compatibility, Radio-Noise Emissions from Low Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz, Methods of Measurement
- ANSI/IEEE C63.14 - Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD)
- ANSI/NCSL Z540-1 - General Requirements for Calibration Laboratories and Measuring and Test Equipment

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

- ASTM E 380 - Standard for Metric Practice (DoD adopted)

INTERNATIONAL STANDARDS ORGANIZATION

- ISO 10012-1 - Quality Assurance Requirements for Measuring Equipment

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

- ARP 958 - Electromagnetic Interference Measurement Antennas; Standard Calibration Requirements and Methods

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2.3 Order of precedence.

In the event of a conflict between the text of this standard and the references cited herein, the text of this standard shall take precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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3. DEFINITIONS

3.1 General.

The terms used in this standard are defined in ANSI C63.14. In addition, the following definitions are applicable for the purpose of this standard.

3.2 Acronyms used in this standard.

- a. ASW - Anti-submarine Warfare
- b. BIT - Built-in Test
- c. EMC - Electromagnetic Compatibility
- d. EME - Electromagnetic Environment
- e. EMI - Electromagnetic Interference
- f. EMICP - Electromagnetic Interference Control Procedures
- g. EMITP - Electromagnetic Interference Test Procedures
- h. EMITR - Electromagnetic Interference Test Report
- i. ERP - Effective Radiated Power
- j. EUT - Equipment Under Test
- k. GFE - Government Furnished Equipment
- l. ISM - Industrial, Scientific and Medical
- m. LISN - Line Impedance Stabilization Network
- n. NDI - Non-Developmental Item
- o. RF - Radio Frequency
- p. RMS - Root Mean Square
- q. TEM - Transverse Electromagnetic
- r. TPD - Terminal Protection Device

3.5 External installation.

An equipment location on a platform which is exposed to the external electromagnetic environment, such as an aircraft cockpit which does not use electrically conductive treatments on the canopy or windscreen.

3.6 Flight-line equipment.

Any support equipment that is attached to or used next to an aircraft during pre-flight or post-flight operations, such as uploading or downloading data, maintenance diagnostics, or equipment functional testing.

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3.7 Internal installation.

An equipment location on a platform which is totally inside an electrically conductive structure, such as a typical avionics bay in an aluminum skin aircraft.

3.8 Metric units.

Metric units are a system of basic measures which are defined by the International System of Units based on "Le System International d'Unites (SI)", of the International Bureau of Weights and Measures. These units are described in ASTM E 380.

3.9 Non-developmental item.

Non-developmental item is a broad, generic term that covers material available from a wide variety of sources both Industry and Government with little or no development effort required by the procuring activity.

3.10 Safety critical.

A category of subsystems and equipment whose degraded performance could result in loss of life or loss of vehicle or platform.

3.11 Test setup boundary.

The test setup boundary includes all enclosures of the Equipment Under Test (EUT) and the 2 meters of exposed interconnecting leads (except for leads which are shorter in the actual installation) and power leads required by 4.3.8.6.

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4. SAFETY/QUALITY ASSURANCE INFORMATION

4.1 General safety requirements.

Each individual participating in EMI Facility and EMI/EMC test operations is responsible for compliance with safety regulations.

Normal safety procedures for laboratory environments as identified in MPG 1700.1, MSFC Industrial Safety Procedures and Guidelines, will be observed.

During radiated susceptibility test where high power levels of RF energy is being radiated through antennas to articles under test, it is mandatory that the doors of the shielded enclosure where the test is being conducted be closed and secured. This is a requirement to reduce to safe levels power densities that may exceed the maximum permissible exposure to personnel in the immediate area. Reference IEEE C95.1-1991 Standard for Safety Levels with Respect to Human Exposure to RF Electromagnetic Fields, 3kHz to 300GHz.

4.2 Safety critical/hazardous operations.

No safety critical or hazardous operations are associated with this procedure.

4.3 Personnel protective equipment (PPE).

Any requirements for PPE during EMI/EMC testing that is unique to the Test Article shall be identified by the customer in the customer agreement process and shall be the responsibility of the customer.

4.4 Hardware handling.

Handling of Test Articles designated for EMI/EMC testing will be the responsibility of the test requester as mutually agreed upon in the Customer Agreement process.

4.5 Cleanliness Requirements.

The EMI Facility is an environmentally controlled test area maintained to 300K clean room requirements. Normal clean room operations typical of a 300K clean room as identified in **OWI-EL62-009**, Clean Room Operations will be observed

The customer must read applicable sections of the **OWI-EL62-009**, 300K clean room operations, and agree to the rules by signing the applicable clean room signature sheet.

4.4 Electrostatic Discharge Requirements.

If a Test Article designated for EMI/EMC testing is identified as ESD sensitive, then it is the responsibility of the test requestor to identify all areas of ESD sensitivity, grounding requirements and special handling in the Customer Agreement process.

A certified ESD work station is available in the EMI/EMC Facility to support any requirements that a customer may have.

4.5 Grounding requirements.

The METF power distribution and grounding will be operated to the terms identified in the appropriate sections of the standards, specifications and requirements of EMI/EMC testing. Specific power supply grounding or ground isolation will be identified by the test requestor in the Customer Agreement process.

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4.6 Electrical conventions.

The following color conventions will be used on test leads during the course of EMI/EMC testing and on Test Article operations and setup.

| | |
|----------------------------|--|
| Earth or structural ground | Green |
| DC common or return | Black or Green (if tied to earth or structural ground) |
| DC voltages above ground | Red |
| DC voltages below ground | Yellow |

4.7 Emergency telephone numbers.

| | |
|------------|-----------------|
| Fire | 911 |
| Ambulance | 911 |
| Security | 4-4357 Option 1 |
| Facilities | 4-4357 Option 4 |
| Team Lead | 4-2394 |

4.8 Emergency shutdown procedures.

In case of an emergency, perform the emergency shutdown procedures located in Section 4.9, identified by the yellow page.

In the event of severe weather during test operations, perform the emergency shutdown procedure and proceed immediately to the proper shelter area. **Reference MM1040.3D - MSFC Emergency Plan**

The **ED44 safety monitor and alternate** will make every effort to advise the EMI Test Facility and Test Article operators of any planned fire drills. If properly notified, testing may continue during a planned fire drill. However, if the fire alarm sounds and it cannot be verified that a fire drill is taking place, perform the emergency shutdown procedure, then evacuate the EMI Test Facility and building.

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4.9 EMERGENCY PROCEDURES

The following operational conditions could constitute an emergency condition requiring immediate attention or power removal.

- Test article exceeds normal operational current limits.
- Electrical problems resulting in visible smoke, arcing, sparks, excessive heating, unusual sounds etc. with the Test Article or with the EMI/EMC test facility

4.9.1 Power removal.

- Open Test Article power supply circuit breakers.
- Turn off power supplies
- Turn off Test Article supporting GSE.
- Turn off EMI/EMC test facility test equipment and control console.
- In the event that a unexpected and complete EMI/EMC test facility shutdown is required, hit with the open palm of the hand, any of the red Emergency Power Off, **EPO**, switches located in the shielded enclosure test areas. Ref: Figure 1 - EMI/EMC Test Facility Control Layout diagram in Section 7.0 of this procedure.

4.9.2 Water sprinkler deactivation.

Should an event occur where smoke has been released into the EMI/EMC Facility and has been brought under full control, it may be necessary to deactivate the water sprinkler system. **NOTE: This action has to be accomplished within 30 seconds of the METF fire system alarm activation.**

At the Fire Alarm Abort switch directly in front of the METF entrance door, perform the following:

- Raise switch guard.
- Place switch to the up position to abort.
- Verify system aborted LED is on.

Notify proper authorities and supervisor personnel as soon as possible.

| | |
|------------|-----------------|
| Fire | 911 |
| Ambulance | 911 |
| Security | 4-4357 Option 1 |
| Facilities | 4-4357 Option 4 |
| Team Lead | 4-2394 |

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4. GENERAL REQUIREMENTS

4.1 Verification requirements.

The general requirements related to test procedures, test facilities, and equipment stated below, together with the detailed test procedures included in 5.0, shall be used to determine compliance with the applicable emission and susceptibility requirements of this standard. Any procuring activity approved exceptions or deviations from these general requirements shall be documented in the Electromagnetic Interference Test Procedures (EMITP). Equipment that are intended to be operated as a subsystem shall be tested as such to the applicable emission and susceptibility requirements whenever practical. Formal testing is not to commence without approval of the EMITP by the Command or agency concerned. Data that is gathered as a result of performing tests in one electromagnetic discipline may be sufficient to satisfy requirements in another. Therefore, to avoid unnecessary duplication, a single test program should be established with tests for similar requirements conducted concurrently whenever possible.

4.1.1 Measurement tolerances.

Unless otherwise stated for a particular measurement, the tolerance shall be as follows:

- a. Distance: $\pm 5\%$
- b. Frequency: $\pm 2\%$
- c. Amplitude, measurement receiver: ± 2 dB
- d. Amplitude, measurement system (includes measurement receivers, transducers, cables, and so forth): ± 3 dB
- e. Time (waveforms): $\pm 5\%$
- f. Resistors: $\pm 5\%$
- e. Capacitors: $\pm 20\%$

4.1.2 Shielded enclosures.

To prevent interaction between the EUT and the outside environment, shielded enclosures will usually be required for testing. These enclosures prevent external environment signals from contaminating emission measurements and susceptibility test signals from interfering with electrical and electronic items in the vicinity of the test facility. Shielded enclosures must have adequate attenuation such that the ambient requirements of 4.3.4 are satisfied. The enclosures must be sufficiently large such that the EUT arrangement requirements of paragraph 4.3.8 and antenna positioning requirements described in the individual test procedures are satisfied.

METF is located in MSFC Building 4708 Room 1191. The facility consists of four shielded enclosures connected together as shown in Figure 1. The four shielded enclosures consist of a box level room, rack level room, instrumentation room, and an amplifier room. The large test chamber, used for testing systems and large test items, is 24 feet wide, 28 feet deep, and 20 feet high. This is designated as the rack shielded enclosure in Figure 1. The small test chamber, used for testing subsystems and small test items, is 20 feet wide, 28 feet deep, and 14 feet high. This is designated as the box shielded enclosure in Figure 1. The instrumentation room measures 12 feet

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wide, 18 feet deep, and 10 feet high. The amplifier room measures 12 feet wide, 10 feet deep, and 10 feet tall. All sides of each room are constructed of quarter inch steel plate.

The rack and box level chambers are fully lined with radio frequency (RF) absorber. The RF absorber characteristics are discussed in Section 4.3.2.1. Each test chamber has a large door for EUT delivery and a smaller personnel door. All doors are pneumatically sealed sliding doors that maintain the steel double-walled enclosure integrity. All door mating surfaces are flame sprayed with tin. Ceiling and wall penetrations include 21 sprinkler penetrations, 18 vent penetrations, 16 filter penetrations, and 5 access panels.

The box level and rack level shield room attenuation requirements are shown in Table I. The Instrumentation and Amplifier shield room attenuation requirements are shown in Table II. These requirements have been verified using the procedures of Specification NSA No. 65-6, National Security Agency Specification for R.F. Shielded Enclosures for Communications Equipment: General Specification. Both box level and rack level test chamber ambient RE102 and RE101 levels are a minimum of 6dB below the MIL-STD-461E limits.

TABLE I. METF box and rack room attenuation requirements.

| Frequency | Field Type | Attenuation (dB) |
|-----------|------------|------------------|
| 60 Hz | Magnetic | 24 |
| 1 kHz | Magnetic | 20 |
| 15 kHz | Magnetic | 75 |
| 250 kHz | Magnetic | 100 |
| 1 MHz | Magnetic | 100 |
| 30 Hz | Electric | 25 |
| 1 kHz | Electric | 70 |
| 10 kHz | Electric | 100 |
| 100 kHz | Electric | 100 |
| 1 MHz | Electric | 100 |
| 10 MHz | Electric | 100 |
| 100 MHz | Plane Wave | 100 |
| 400 MHz | Plane Wave | 100 |
| 1 GHz | Plane Wave | 100 |
| 12 GHz | Plane Wave | 100 |

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TABLE II. METF instrumentation and amplifier room attenuation requirements.

| Frequency | Field Type | Attenuation (dB) |
|-----------|------------|------------------|
| 1 kHz | Magnetic | 20 |
| 10 kHz | Magnetic | 55 |
| 100 kHz | Magnetic | 90 |
| 1 MHz | Magnetic | 100 |
| 1 kHz | Electric | 70 |
| 10 kHz | Electric | 100 |
| 100 kHz | Electric | 100 |
| 1 MHz | Electric | 100 |
| 10 MHz | Electric | 100 |
| 100 MHz | Plane Wave | 100 |
| 400 MHz | Plane Wave | 100 |
| 1 GHz | Plane Wave | 100 |
| 12 GHz | Plane Wave | 100 |

4.1.2.1 Radio Frequency (RF) absorber material.

RF absorber material (carbon impregnated foam pyramids, ferrite tiles, and so forth) shall be used when performing electric field radiated emissions or radiated susceptibility testing inside a shielded enclosure to reduce reflections of electromagnetic energy and to improve accuracy and repeatability. The RF absorber shall be placed above, behind, and on both sides of the EUT, and behind the radiating or receiving antenna as shown in Figure 2. Minimum performance of the material shall be as specified in Table III. The manufacturer's certification of their RF absorber material (basic material only, not installed) is acceptable.

TABLE III. Absorption at normal incidence.

| Frequency | Minimum absorption |
|------------------|--------------------|
| 80 MHz - 250 MHz | 6 dB |
| above 250 MHz | 10 dB |

METF utilizes Advanced Electromagnetics Incorporated (AEMI) AEP-12 12 inch pyramidal absorber on all walls and ceiling in each test chamber. This exceeds the MIL-STD-461E coverage required in Figure 2. The absorption at normal incidence is plotted versus the MIL-STD-461E requirement in Figure 3. Note that the absorber does not meet the MIL-STD-461E absorption requirements in the 80 MHz-100 MHz frequency range. At 80 MHz the METF absorber provides 3.5 dB attenuation, rather than the required 6 dB. This is 2.5dB below the requirement. The 2.5 dB difference becomes 0 dB by 100MHz. In the 100MHz-20GHz frequency range the METF absorber greatly exceeds the MIL-STD-461E absorption requirements.

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4.1.4 Ambient electromagnetic level.

During testing, the ambient electromagnetic level measured with the EUT de-energized and all auxiliary equipment turned on shall be at least 6 dB below the allowable specified limits when the tests are performed in a shielded enclosure. Ambient conducted levels on power leads shall be measured with the leads disconnected from the EUT and connected to a resistive load which draws the same rated current as the EUT. When tests are performed in a shielded enclosure and the EUT is in compliance with required limits, the ambient profile need not be recorded in the EMITR.

4.1.5 Ground plane.

The EUT shall be installed on a ground plane that simulates the actual installation. If the actual installation is unknown or multiple installations are expected, then a metallic ground plane shall be used. Unless otherwise specified below, ground planes shall be 2.25 square meters or larger in area with the smaller side no less than 76 centimeters. When a ground plane is not present in the EUT installation, the EUT shall be placed on a non-conductive table.

4.1.5.1 Metallic ground plane.

When the EUT is installed on a metallic ground plane, the ground plane shall have a surface resistance no greater than 0.1 milliohms per square. The DC resistance between metallic ground planes and the shielded enclosure shall be 2.5 milliohms or less. The metallic ground planes shown in Figures 2 through 5 shall be electrically bonded to the floor or wall of the basic shielded room structure at least once every 1 meter. The metallic bond straps shall be solid and maintain a five-to-one ratio or less in length to width. Metallic ground planes used outside a shielded enclosure shall extend at least 1.5 meters beyond the test setup boundary in each direction.

Each METF test chamber has a non-conductive EUT test table with 90cm height. The tabletop is completely covered by 1/8" copper stock. The copper tabletop is bonded to the shielded enclosure every 35.5" with 1/16" copper stock straps which are 12" wide and less than 59" long. This provides a good RF bond between the test tabletop and the shielded enclosure. The nominal tabletop size is 8 ft long by 3 ft wide, but can be extended to 12 ft long by 6 ft wide for large test items.

For EUTs with metal enclosures mounted to a metal structure in the actual equipment installation, the EUT is bonded to the copper table top using contact between the EUT and the tabletop and either a braided metal strap or copper tape. The bonding simulates the actual installation as closely as possible.

4.1.5.2 Composite ground plane.

When the EUT is installed on a conductive composite ground plane, the surface resistivity of the typical installation shall be used. Composite ground planes shall be electrically bonded to the enclosure with means suitable to the material.

4.1.6 Power source impedance.

The impedance of power sources providing input power to the EUT shall be controlled by Line Impedance Stabilization Networks (LISNs) for all measurement procedures of this document

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unless otherwise stated in a particular test procedure. LISNs shall not be used on output power leads. The LISNs shall be located at the power source end of the exposed length of power leads specified in paragraph 4.3.8.6.2. The LISN circuit shall be in accordance with the schematic shown in Figure 6. The LISN impedance characteristics shall be in accordance with Figure 7. The LISN impedance shall be measured at least annually under the following conditions:

- a. The impedance shall be measured between the power output lead on the load side of the LISN and the metal enclosure of the LISN.
- b. The signal output port of the LISN shall be terminated in fifty ohms.
- c. The power input terminal on the power source side of the LISN shall be unterminated.

The impedance measurement results shall be provided in the EMITR.

4.1.7 General test precautions.

4.1.7.1 Accessory equipment.

Accessory equipment used in conjunction with measurement receivers shall not degrade measurement integrity.

4.1.7.2 Excess personnel and equipment.

The test area shall be kept free of unnecessary personnel, equipment, cable racks, and desks. Only the equipment essential to the test being performed shall be in the test area or enclosure. Only personnel actively involved in the test shall be permitted in the enclosure.

4.1.7.3 Overload precautions.

Measurement receivers and transducers are subject to overload, especially receivers without preselectors and active transducers. Periodic checks shall be performed to assure that an overload condition does not exist. Instrumentation changes shall be implemented to correct any overload condition.

4.1.7.4 RF hazards.

Some tests in this standard will result in electromagnetic fields which are potentially dangerous to personnel. The permissible exposure levels in DoDI 6055.11 shall not be exceeded in areas where personnel are present. Safety procedures and devices shall be used to prevent accidental exposure of personnel to RF hazards.

4.1.7.5 Shock hazard.

Some of the tests require potentially hazardous voltages to be present. Extreme caution must be taken by all personnel to assure that all safety precautions are observed.

4.1.7.6 Federal Communications Commission (FCC) restrictions.

Some of the tests require high level signals to be generated that could interfere with normal FCC approved frequency assignments. All such testing should be conducted in a shielded enclosure. Some open site testing may be feasible if prior FCC coordination is accomplished.

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4.1.8 EUT test configurations.

The EUT shall be configured as shown in the general test setups of Figures 1 through 5 as applicable. These setups shall be maintained during all testing unless other direction is given for a particular test procedure.

4.1.8.1 EUT design status.

EUT hardware and software shall be representative of production. Software may be supplemented with additional code that provides diagnostic capability to assess performance.

4.1.8.2 Bonding of EUT.

Only the provisions included in the design of the EUT shall be used to bond units such as equipment case and mounting bases together, or to the ground plane. When bonding straps are required, they shall be identical to those specified in the installation drawings.

4.1.8.3 Shock and vibration isolators.

EUTs shall be secured to mounting bases having shock or vibration isolators if such mounting bases are used in the installation. The bonding straps furnished with the mounting base shall be connected to the ground plane. When mounting bases do not have bonding straps, bonding straps shall not be used in the test setup.

4.1.8.4 Safety grounds.

When external terminals, connector pins, or equipment grounding conductors are available for safety ground connections and are used in the actual installation, they shall be connected to the ground plane. Arrangement and length shall be in accordance with 4.3.8.6.1.

4.1.8.5 Orientation of EUTs.

EUTs shall be oriented such that surfaces which produce maximum radiated emissions and respond most readily to radiated signals face the measurement antennas. Bench mounted EUTs shall be located 10 ± 2 centimeters from the front edge of the ground plane subject to allowances for providing adequate room for cable arrangement as specified below.

4.1.8.6 Construction and arrangement of EUT cables.

Electrical cable assemblies shall simulate actual installation and usage. Shielded cables or shielded leads (including power leads and wire grounds) within cables shall be used only if they have been specified in installation requirements. Cables shall be checked against installation requirements to verify proper construction techniques such as use of twisted pairs, shielding, and shield terminations. Details on the cable construction used for testing shall be included in the EMITP.

4.1.8.6.1 Interconnecting leads and cables.

Individual leads shall be grouped into cables in the same manner as in the actual installation. Total interconnecting cable lengths in the setup shall be the same as in the actual platform installation. If a cable is longer than 10 meters, at least 10 meters shall be included. When cable lengths are not specified for the installation, cables shall be sufficiently long to satisfy the conditions specified below. At least the first 2 meters (except for cables which are shorter in the actual installation) of each interconnecting cable associated with each enclosure of the EUT shall be run parallel to the front boundary of the setup. Remaining cable lengths shall be routed to the

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back of the setup and shall be placed in a zig-zagged arrangement. When the setup includes more than one cable, individual cables shall be separated by 2 centimeters measured from their outer circumference. For bench top setups using ground planes, the cable closest to the front boundary shall be placed 10 centimeters from the front edge of the ground plane. All cables shall be supported 5 centimeters above the ground plane.

4.1.8.6.2 Input power leads.

Two meters of input power leads (including neutrals and returns) shall be routed parallel to the front edge of the setup in the same manner as the interconnecting leads. Each input power lead, including neutrals and returns, shall be connected to a LISN (see 4.3.6). Power leads that are bundled as part of an interconnecting cable in the actual installation shall be configured in the same fashion for the 2 meter exposed length and then shall be separated from the bundle and routed to the LISNs. After the 2 meter exposed length, the power leads shall be terminated at the LISNs in as short a distance as possible. The total length of power lead from the EUT electrical connector to the LISNs shall not exceed 2.5 meters. All power leads shall be supported 5 centimeters above the ground plane. If the power leads are twisted in the actual installation, they shall be twisted up to the LISNs.

4.1.8.7 Electrical and mechanical interfaces.

All electrical input and output interfaces shall be terminated with either the actual equipment from the platform installation or loads which simulate the electrical properties (impedance, grounding, balance, and so forth) present in the actual installation. Signal inputs shall be applied to all applicable electrical interfaces to exercise EUT circuitry. EUTs with mechanical outputs shall be suitably loaded. When variable electrical or mechanical loading is present in the actual installation, testing shall be performed under expected worst case conditions. When active electrical loading (such as a test set) is used, precautions shall be taken to insure the active load meets the ambient requirements of 4.3.4 when connected to the setup, and that the active load does not respond to susceptibility signals. Antenna ports on the EUT shall be terminated with shielded, matched loads.

4.1.9 Operation of EUT.

During emission measurements, the EUT shall be placed in an operating mode which produces maximum emissions. During susceptibility testing, the EUT shall be placed in its most susceptible operating mode. For EUTs with several available modes (including software controlled operational modes), a sufficient number of modes shall be tested for emissions and susceptibility such that all circuitry is evaluated. The rationale for modes selected shall be included in the EMITP.

4.1.9.1 Operating frequencies for tunable RF equipment.

Measurements shall be performed with the EUT tuned to not less than three frequencies within each tuning band, tuning unit, or range of fixed channels, consisting of one mid-band frequency and a frequency within ± 5 percent from each end of each band or range of channels.

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4.1.9.2 Operating frequencies for spread spectrum equipment.

Operating frequency requirements for two major types of spread spectrum equipment shall be as follows:

- a. Frequency hopping. Measurements shall be performed with the EUT utilizing a hop set which contains a minimum of 30% of the total possible frequencies. This hop set shall be divided equally into three segments at the low, mid, and high end of the EUT's operational frequency range.
- b. Direct sequence. Measurements shall be performed with the EUT processing data at the highest possible data transfer rate.

4.1.9.3 Susceptibility monitoring.

The EUT shall be monitored during susceptibility testing for indications of degradation or malfunction. This monitoring is normally accomplished through the use of built-in-test (BIT), visual displays, aural outputs, and other measurements of signal outputs and interfaces. Monitoring of EUT performance through installation of special circuitry in the EUT is permissible; however, these modifications shall not influence test results.

4.1.10 Use of measurement equipment.

Measurement equipment shall be as specified in the individual test procedures of this standard. Any frequency selective measurement receiver may be used for performing the testing described in this standard provided that the receiver characteristics (that is, sensitivity, selection of bandwidths, detector functions, dynamic range, and frequency of operation) meet the constraints specified in this standard and are sufficient to demonstrate compliance with the applicable limits. Typical instrumentation characteristics may be found in ANSI C63.2.

4.1.10.1 Detector.

A peak detector shall be used for all frequency domain emission and susceptibility measurements. This device detects the peak value of the modulation envelope in the receiver bandpass. Measurement receivers are calibrated in terms of an equivalent Root Mean Square (RMS) value of a sine wave that produces the same peak value. When other measurement devices such as oscilloscopes, non-selective voltmeters, or broadband field strength sensors are used for susceptibility testing, correction factors shall be applied for test signals to adjust the reading to equivalent RMS values under the peak of the modulation envelope.

4.1.10.2 Computer-controlled receivers.

A description of the operations being directed by software for computer-controlled receivers shall be included in the EMITP. Verification techniques used to demonstrate proper performance of the software shall also be included.

4.1.10.3 Emission testing.

4.1.10.3.1 Bandwidths.

The measurement receiver bandwidths listed in Table II shall be used for emission testing. These bandwidths are specified at the 6 dB down points for the overall selectivity curve of the receivers. Video filtering shall not be used to bandwidth limit the receiver response. If a

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controlled video bandwidth is available on the measurement receiver, it shall be set to its greatest value. Larger receiver bandwidths may be used; however, they may result in higher measured emission levels. NO BANDWIDTH CORRECTION FACTORS SHALL BE APPLIED TO TEST DATA DUE TO THE USE OF LARGER BANDWIDTHS.

TABLE II. Bandwidth and measurement time.

| Frequency Range | 6 dB Bandwidth | Dwell Time | Minimum Measurement Time Analog Measurement Receiver |
|------------------|----------------|------------|---|
| 30 Hz - 1 kHz | 10 Hz | 0.15 sec | 0.015 sec/Hz |
| 1 kHz - 10 kHz | 100 Hz | 0.015 sec | 0.15 sec/kHz |
| 10 kHz - 150 kHz | 1 kHz | 0.015 sec | 0.015 sec/kHz |
| 150 kHz - 30 MHz | 10 kHz | 0.015 sec | 1.5 sec/MHz |
| 30 MHz - 1 GHz | 100 kHz | 0.015 sec | 0.15 sec/MHz |
| Above 1 GHz | 1 MHz | 0.015 sec | 15 sec/GHz |

4.1.10.3.2 Emission identification.

All emissions regardless of characteristics shall be measured with the measurement receiver bandwidths specified in Table II and compared against the applicable limits. Identification of emissions with regard to narrowband or broadband categorization is not applicable.

4.1.10.3.3 Frequency scanning.

For emission measurements, the entire frequency range for each applicable test shall be scanned. Minimum measurement time for analog measurement receivers during emission testing shall be as specified in Table II. Synthesized measurement receivers shall step in one-half bandwidth increments or less, and the measurement dwell time shall be as specified in Table II. For equipment that operates such that potential emissions are produced at only infrequent intervals, times for frequency scanning shall be increased as necessary to capture any emissions.

4.1.10.3.4 Emission data presentation.

Amplitude versus frequency profiles of emission data shall be automatically generated and displayed at the time of test and shall be continuous. The displayed information shall account for all applicable correction factors (transducers, attenuators, cable loss, and the like) and shall include the applicable limit. Manually gathered data is not acceptable except for verification of the validity of the output. Plots of the displayed data shall provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less stringent, and minimum amplitude resolution of 1 dB. The above resolution requirements shall be maintained in the reported results of the EMITR.

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4.1.10.4 Susceptibility testing.

4.1.10.4.1 Frequency scanning.

For susceptibility measurements, the entire frequency range for each applicable test shall be scanned. For swept frequency susceptibility testing, frequency scan rates and frequency step sizes of signal sources shall not exceed the values listed in Table III. The rates and step sizes are specified in terms of a multiplier of the tuned frequency (f_o) of the signal source. Analog scans refer to signal sources which are continuously tuned. Stepped scans refer to signal sources which are sequentially tuned to discrete frequencies. Stepped scans shall dwell at each tuned frequency for the greater of 3 seconds or the EUT response time. Scan rates and step sizes shall be decreased when necessary to permit observation of a response.

TABLE III. Susceptibility scanning.

| Frequency Range | Analog Scans Maximum Scan Rates | Stepped Scans Maximum Step Size |
|-----------------|------------------------------------|------------------------------------|
| 30 Hz - 1 MHz | $0.0333f_o/\text{sec}$ | $0.05 f_o$ |
| 1 MHz - 30 MHz | $0.00667 f_o/\text{sec}$ | $0.01 f_o$ |
| 30 MHz - 1 GHz | $0.00333 f_o/\text{sec}$ | $0.005 f_o$ |
| 1 GHz - 8 GHz | $0.000667 f_o/\text{sec}$ | $0.001 f_o$ |
| 8 GHz - 40 GHz | $0.000333 f_o/\text{sec}$ | $0.0005 f_o$ |

4.1.10.4.2 Modulation of susceptibility signals.

Susceptibility test signals for CS114 and RS103 shall be pulse modulated (on/off ratio of 40 dB minimum) at a 1 kHz rate with a 50% duty cycle.

4.1.10.4.3 Thresholds of susceptibility.

When susceptibility indications are noted in EUT operation, a threshold level shall be determined where the susceptible condition is no longer present. Thresholds of susceptibility shall be determined as follows and described in the EMITR:

- When a susceptibility condition is detected, reduce the interference signal until the EUT recovers.
- Reduce the interference signal by an additional 6 dB.
- Gradually increase the interference signal until the susceptibility condition reoccurs. The resulting level is the threshold of susceptibility.
- Record this level, frequency range of occurrence, frequency and level of greatest susceptibility, and other test parameters, as applicable.

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4.1.11 Calibration of measuring equipment.

Test equipment and accessories required for measurement in accordance with this standard shall be calibrated in accordance with ANSI/NCSL Z540-1 or ISO 10012-1 or under an approved calibration program traceable to the National Institute for Standards and Technology. In particular, measurement antennas, current probes, field sensors, and other devices used in the measurement loop shall be calibrated at least every 2 years unless otherwise specified by the procuring activity, or when damage is apparent.

4.1.11.1 Measurement system test.

At the start of each emission test, the complete test system (including measurement receivers, cables, attenuators, couplers, and so forth) shall be verified by injecting a known signal, as stated in the individual test procedure, while monitoring system output for the proper indication. When the emission test involves an uninterrupted set of repeated measurements (such as evaluating different operating modes of the EUT) using the same measurement equipment, the measurement system test needs to be accomplished only one time.

4.1.11.2 Antenna factors.

Factors for test antennas shall be determined in accordance with SAE ARP-958.

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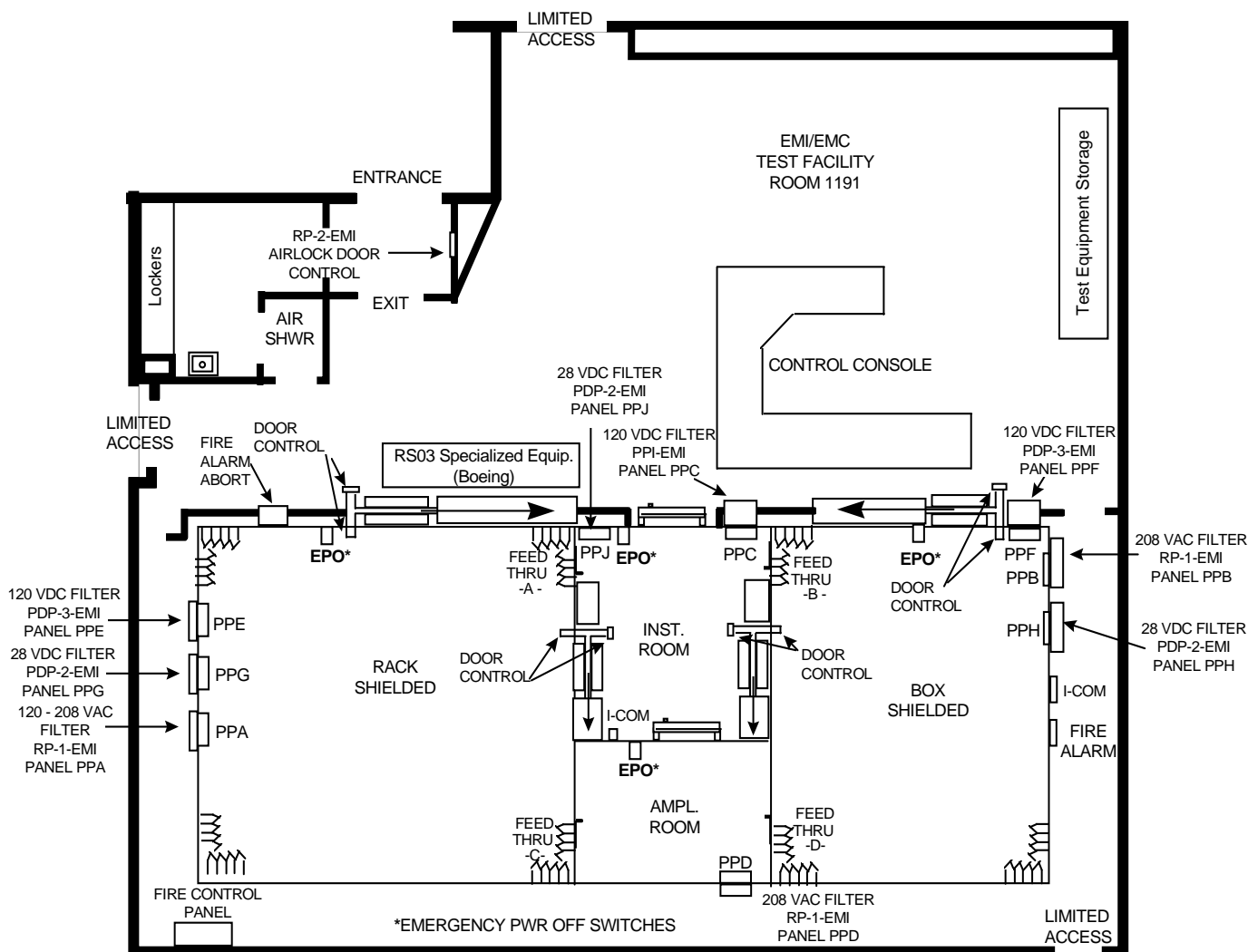


FIGURE 1. MSFC EMI Test Facility.

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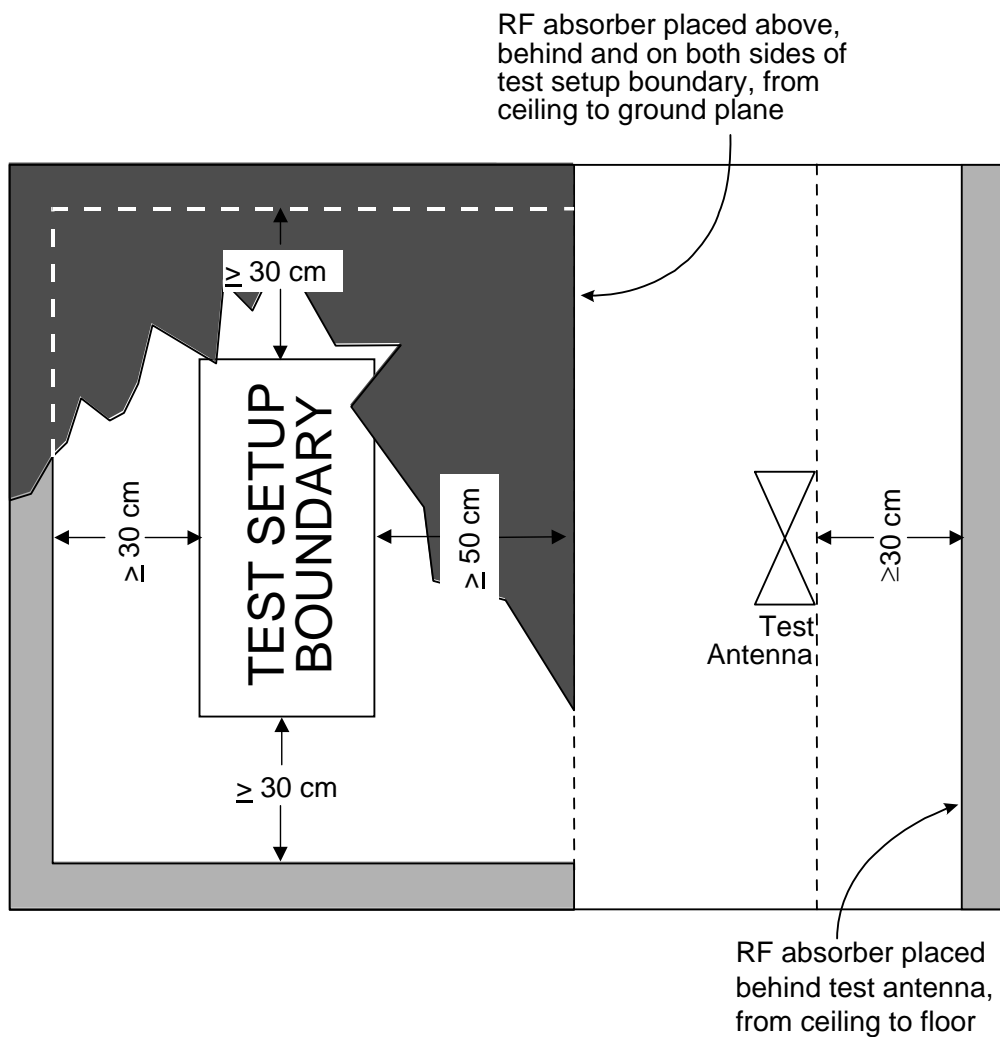


FIGURE 2. RF absorber loading diagram.

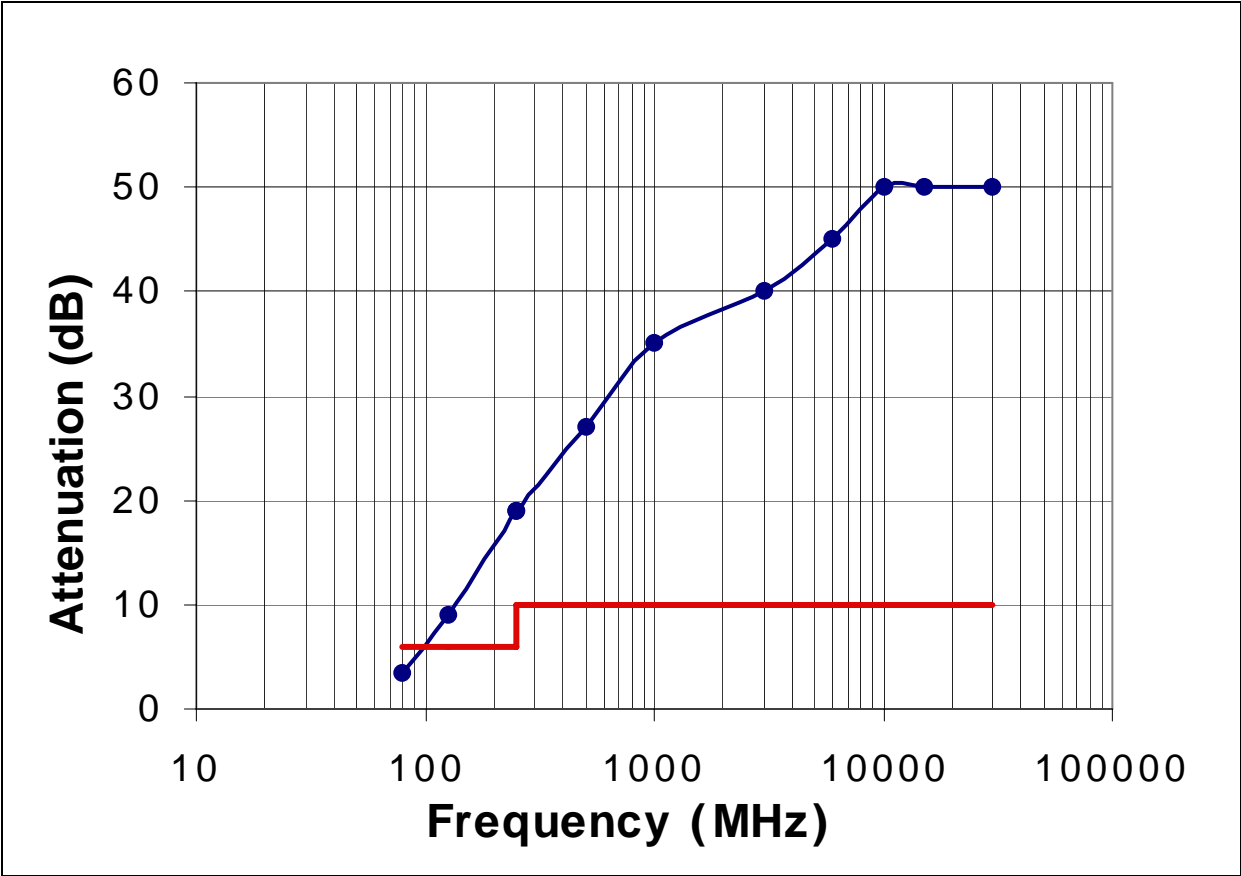


FIGURE 3. METF pyramidal absorber characteristics.

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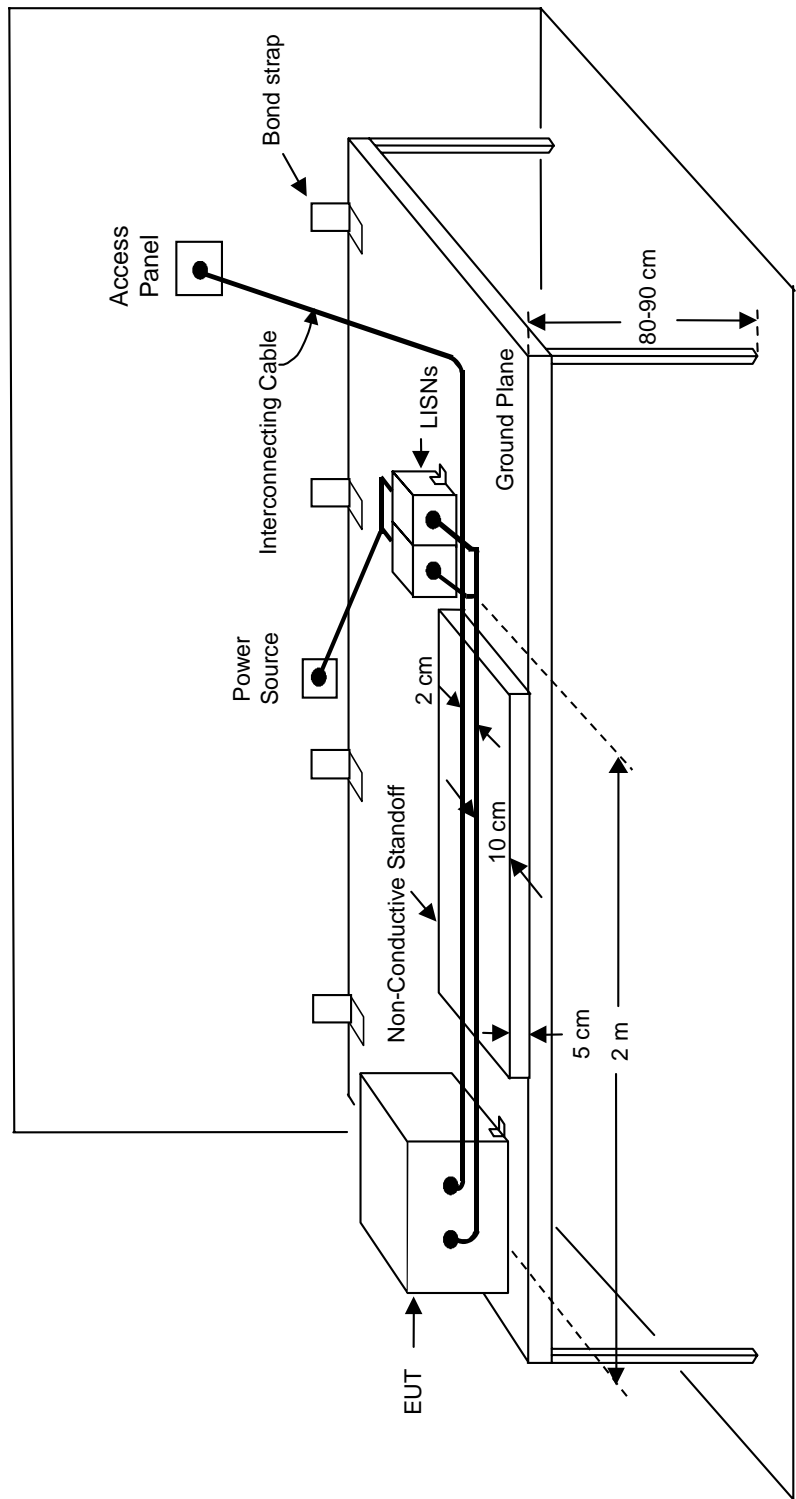


FIGURE 4. General test setup.

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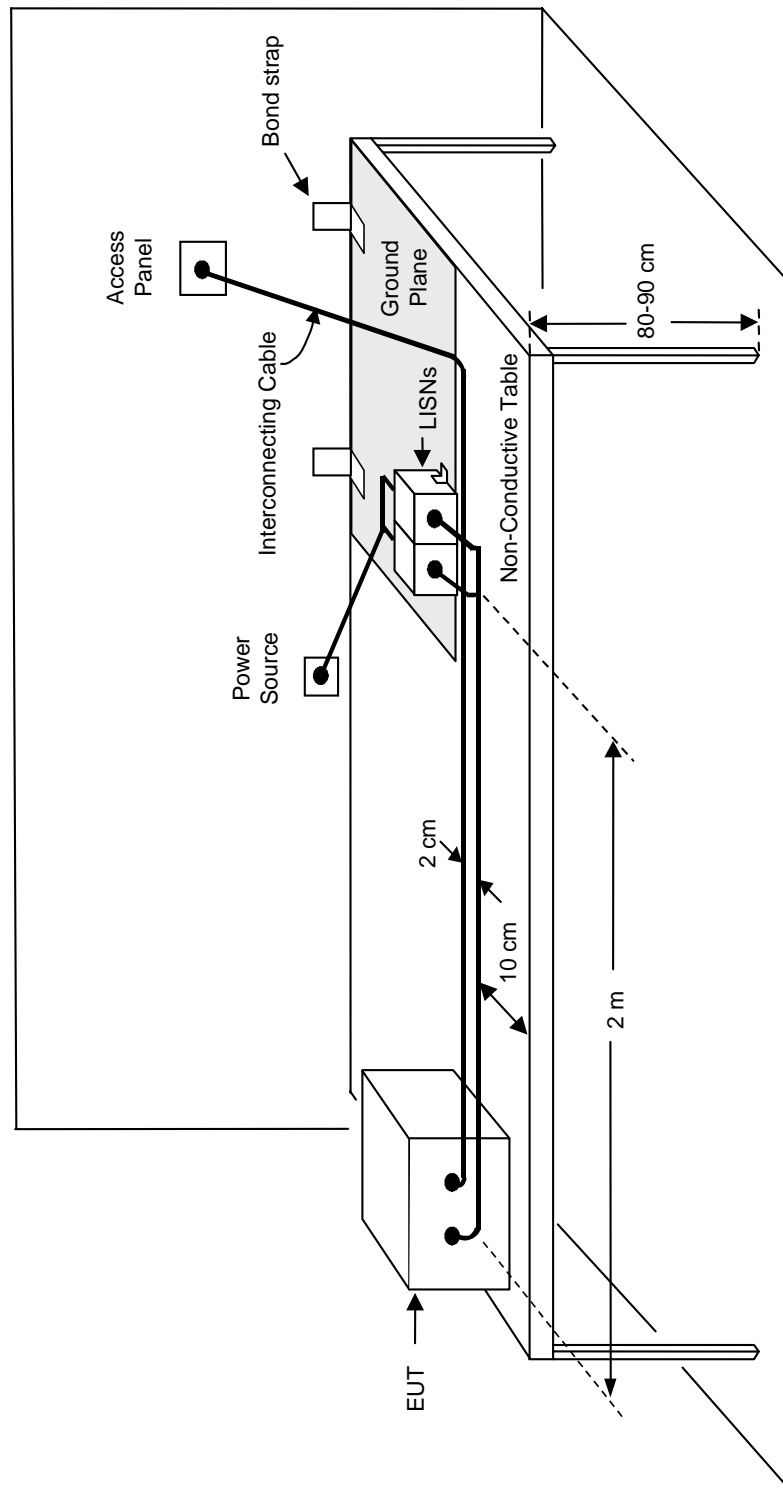


FIGURE 5. Test setup for non-conductive surface mounted EUT.

| | | |
|--|-----------------|------------------------|
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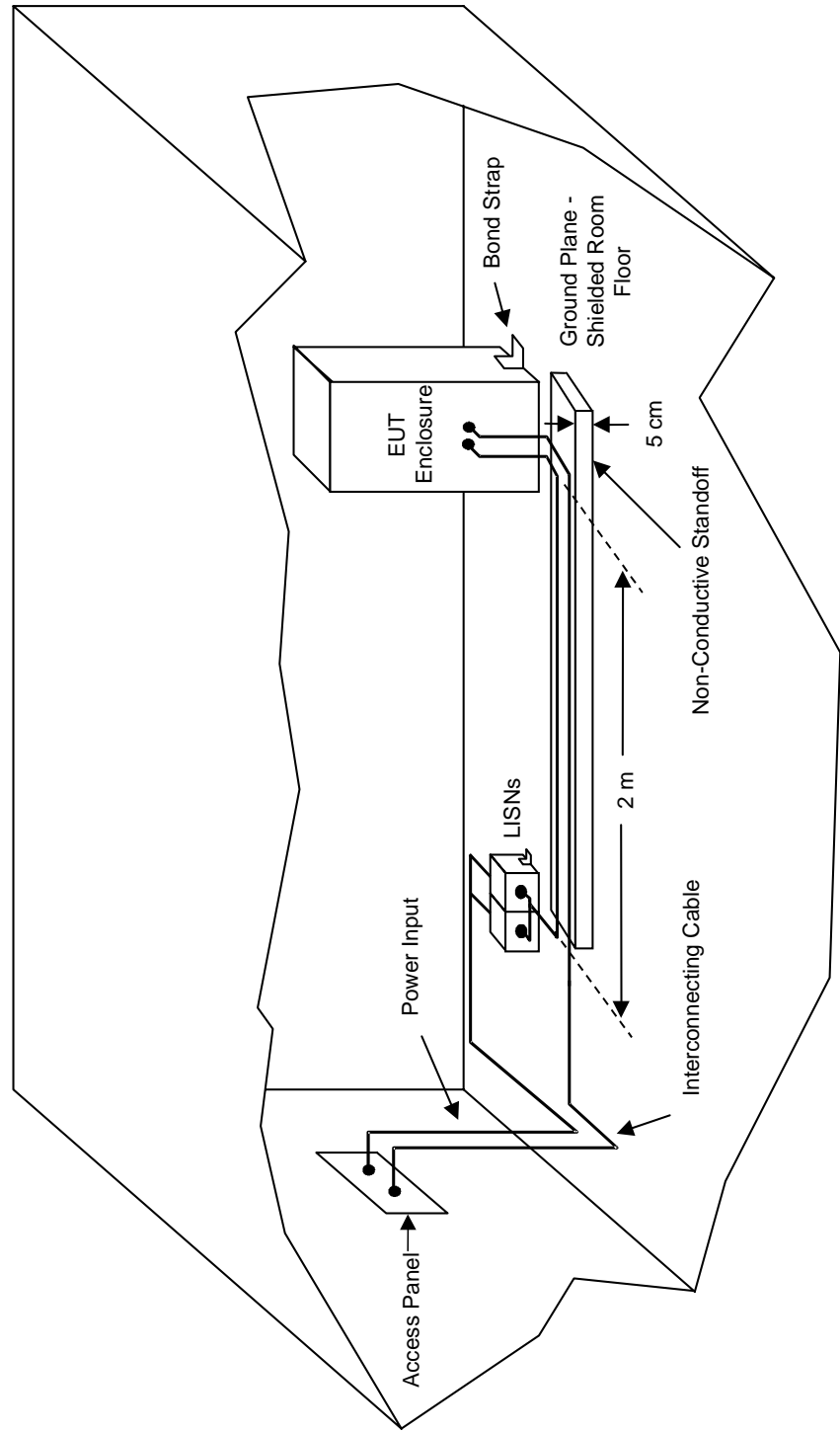


FIGURE 6. Test setup for free standing EUT in shielded enclosure.

| | | |
|--|-----------------|------------------------|
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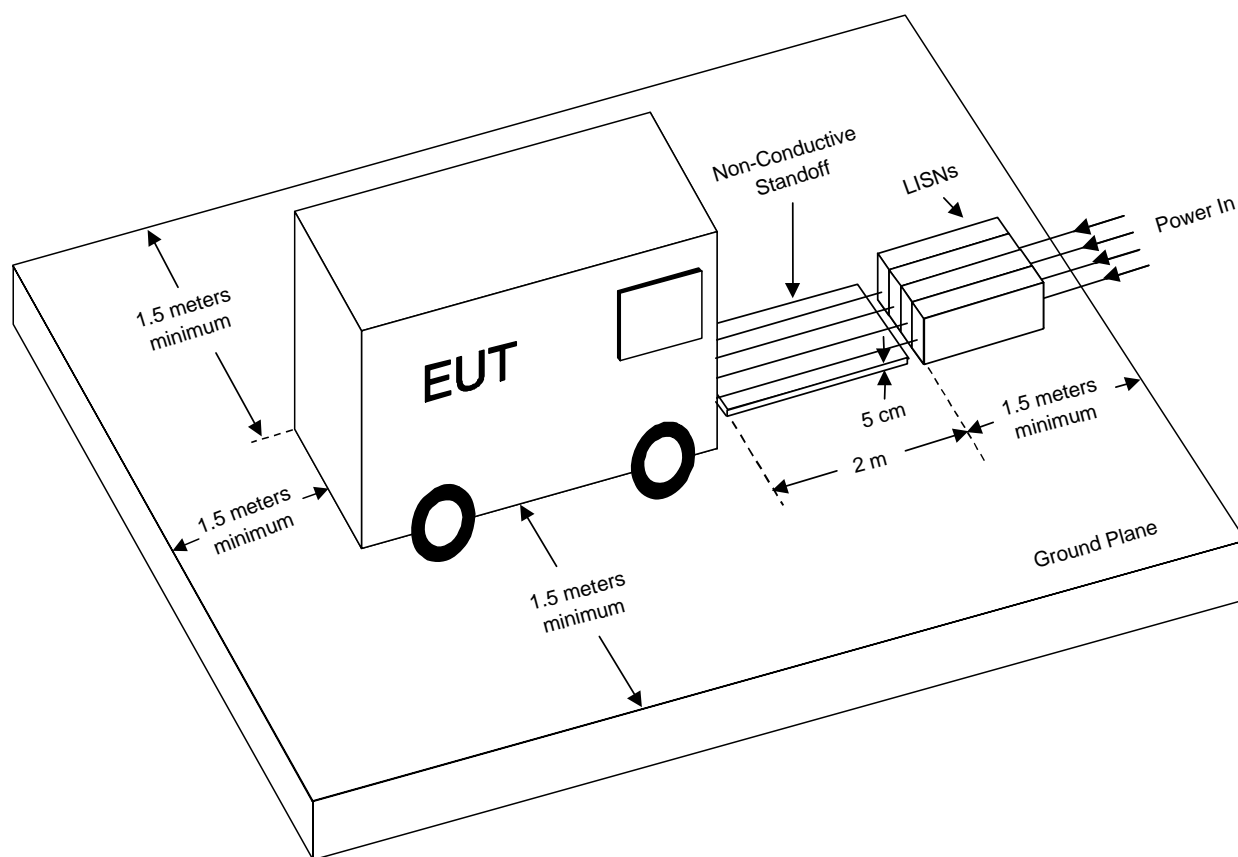


FIGURE 7. Test setup for free standing EUT.

| | | |
|--|-----------------|------------------------|
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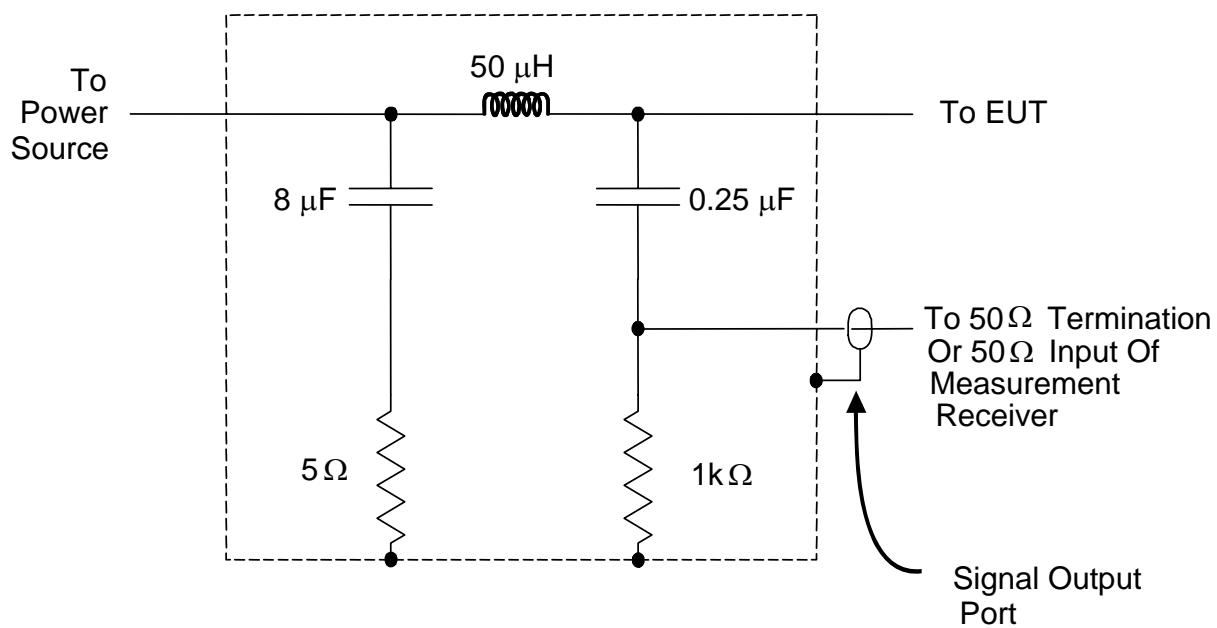


FIGURE 8. LISN schematic.

| | | |
|--|-----------------|------------------------|
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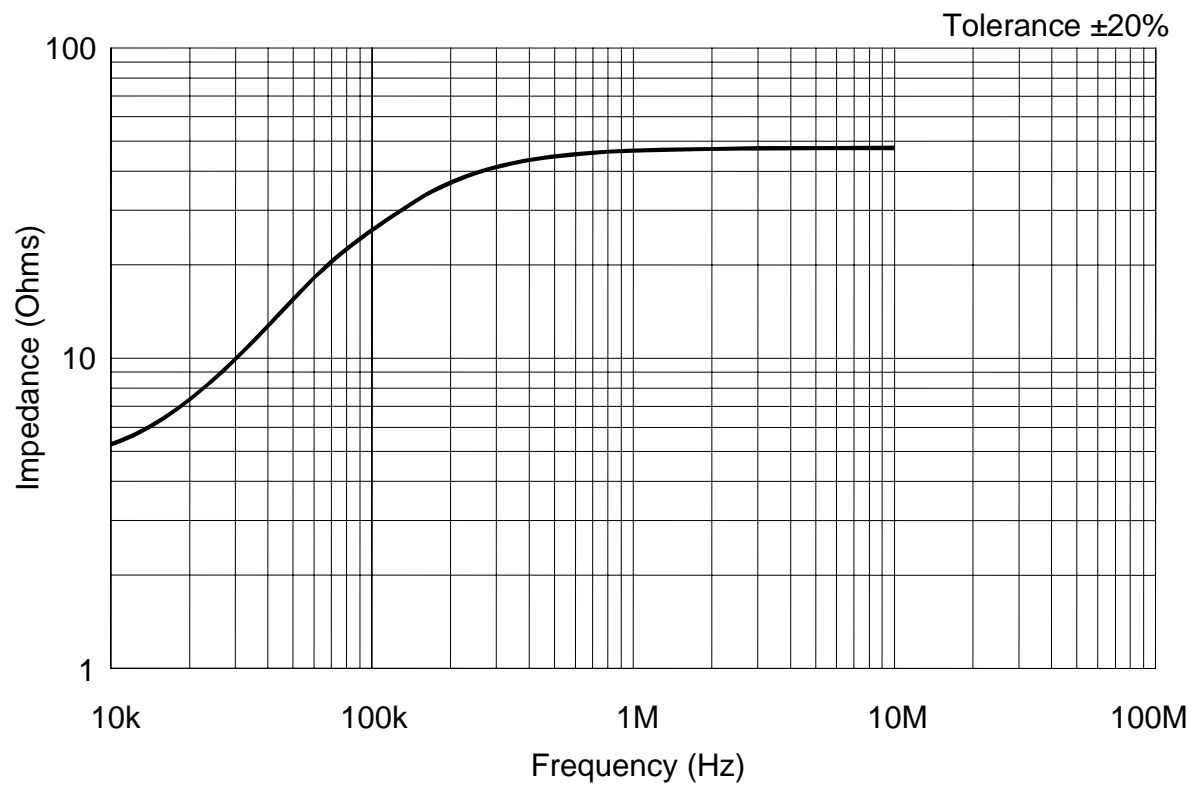


FIGURE 9. LISN impedance.

| | | |
|--|-----------------|------------------------|
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NASA MSFC EMI Test Facility (METF) EUT Test Preparation Sheet

Sheet 1 of 2

CA Start Date: _____
 Setup Date: _____
 Start of test Date: _____
 End of test Date : _____

Project Name: _____ EUT S/N: _____

Customer Agreement Number _____

CSP Tag Number : _____

Equipment Under Test (EUT) operation and monitoring shall be the responsibility of the customer having tests performed at METF

EUT EMI Test Preparations:

- Equipment under test bonding to ground plane measurement: _____mOhm
 (≤ 2.5 mohm)
 Other bonding values : _____

- Install power fuse as required: _____A _____A _____A _____A _____A
 120Vdc 28Vdc 12Vdc -12Vdc 5Vdc
- DC Power Supply voltage: _____Vdc _____Vdc _____Vdc _____Vdc _____Vdc
 120Vdc 28Vdc 12Vdc -12Vdc 5Vdc
- MIL-STD-461E Line Impedance Stabilization Networks (LISNs) installed on all EUT input power leads, LISNs are calibrated, and calibration factors have been included in the test procedure.

Power Bus 1 Power Bus 2 Power Bus 3 Power Bus 4

EUT Test Conductor: _____ Date: _____
 ED44 E3 Test Conductor : _____ Date: _____

| | | |
|--|-----------------|------------------------|
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NASA MSFC EMI Test Facility (METF) EUT Test Preparation Sheet

Sheet 2 of 2

Project Name: _____

EUT EMI Test Preparations (continued):

5. Line Impedance Stabilization Networks (LISNs) shall be bonded to the ground plane. Measure bonding values and record below.

| | | | |
|-------------|-------------|-------------|-------------|
| Power Bus 1 | Power Bus 2 | Power Bus 3 | Power Bus 4 |
| _____ | _____ | _____ | _____ |

6. EUT configured per the general test setups of Figures 2 and 4-7 in this FOP.

- | | |
|---|-------|
| a. All sides of EUT at least 30 cm from test chamber wall | _____ |
| b. Front of EUT located 10cm from ground plane front edge | _____ |
| c. EUT safety grounds connected to ground plane (if applicable) | _____ |
| d. Interconnecting leads/cables (ILC) elevated 5 cm off gnd plane | _____ |
| e. ILC at front of table 10cm back from edge | _____ |
| f. At least 2 meters of each ILC parallel to table front edge | _____ |
| g. ILC longer than 10 meters, at least 10 meters tested | _____ |
| h. Remaining ILC lengths routed to back and zig-zagged | _____ |
| i. Individual ILCs separated by 2 cm | _____ |
| j. ILCs leaving test chamber have cable shield bonded to chamber | _____ |
| k. Power leads (PL) elevated 5 cm off ground plane | _____ |
| l. PL at front of table 10 cm back from edge | _____ |
| m. At least 2 meters of each PL parallel to table front edge | _____ |
| n. For bundled PL, 2 meters parallel to table front edge and then broken out and routed to LISN in as short a distance as possible | _____ |
| o. Total PL length less than 2.5 meters | _____ |
| p. Each PL (hot, return, neutral) connected to a LISN | _____ |

Deviations from the above requirements: _____

EUT Test Conductor: _____ **Date:** _____

ED44 E3 Test Conductor : _____ **Date:** _____

| | | |
|--|-----------------|------------------------|
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NASA MSFC EMI Test Facility (METF)

METF Test Equipment Calibration list

Date: _____ **Project Name:** _____ **Sheet 1 of 4**

| <u>Nomenclature:</u> | <u>Model</u> | <u>Cal ID</u> | <u>Cal Due Date</u> |
|------------------------------------|----------------------|---------------|---------------------|
| CE01 Current Probe | PCL-10 S/N 1617 | M636810 | _____ |
| CE01 Current Probe | PCL-10 S/N 128-A | M646442 | _____ |
| CE01 Current Probe | PCL-10 S/N 4-0101 | M646497 | _____ |
| CE01 Current Probe | PCL-10 S/N 4-0104 | M648433 | _____ |
| CE03 Current Probe | CP-105 S/N 175 | M644315 | _____ |
| CE03 Current Probe | CP-105 S/N 555 | M646496 | _____ |
| RE02 Antenna (rod, 14k – 30M) | 3301B S/N 2795 | M632231 | _____ |
| RE02 Antenna (rod, 14k – 30M) | 3301B S/N 3752 | 1727810 | _____ |
| RE02 Antenna (rod, 14k – 30M) | 3301B S/N 2796 | M637005 | _____ |
| RE02 Antenna (Biconical, 30-220M) | BIA-30S S/N 160 | M650934 | _____ |
| RE02 Antenna (Biconical, 30-220M) | EMCO 3104C S/N4919 | M651418 | _____ |
| RE02 Antenna (log spir, 220M-1G) | Singer93490-1 S/N161 | M625432 | _____ |
| RE02 Antenna (log spir, 220M-1G) | LCA-30 S/N 011 | 1155420 | _____ |
| RE02 Antenna (DRG, 200M-2G) | 3106 S/N 2562 | M651458 | _____ |
| RE02 Antenna (DRG, 200M-2G) | 3106 S/N 2729 | 1963110 | _____ |
| RE02 Antenna (log spir, 1-10G) | ETS 3102 S/N3280 | 2017445 | _____ |
| RE02 Antenna (log spir, 1-10G) | ETS 3102 S/N21062 | 305015 | _____ |
| RE02 Antenna (DRG, 1-18G) | 3115 S/N 5631 | M642380 | _____ |
| RE02 Antenna (DRG, 1-18G) | 3115 S/N 4230 | M651306 | _____ |
| RE02 Antenna (DRG, 1-18G) | 3115 S/N 27001 | M651068 | _____ |
| RE02 Antenna (DRG, 1-18G) | 3115 S/N 27016 | M651067 | _____ |
| RE04 63.5cm loop Antenna | ALP-11 | M637009 | _____ |
| Antenna Log/ Conical | EM-6917A-1 | 1936796 | _____ |
| CSO2 Interface Box | 7415-3 | In house cal | N/A |
| EMI Test Receiver | R/S ES126 S/N 001 | 2015727 | _____ |
| EMI Test Receiver | R/S ES126 S/N 002 | 2015728 | _____ |
| Spectrum Analyzer | HP 8566B | 679679 | _____ |
| RF Preselector | HP 85685A | 1398133 | _____ |
| Spectrum Analyzer Display | HP 85662A | 679680 | _____ |
| Spectrum Analyzer | HP 8566B | 835331 | _____ |
| RF Preselector | HP 85685A | 1535123 | _____ |
| Spectrum Analyzer Display | HP 85662A | 835332 | _____ |
| Spectrum Analyzer | HP 8590L | 1535135 | _____ |
| Spectrum Analyzer | HP 8591E | 1279517 | _____ |
| Optical E-field Probe (220M – 18G) | 7121 S/N 1359 | 010821 | _____ |
| Optical E-field Probe (220M – 18G) | 7121 S/N 1358 | 010822 | _____ |
| Electric Field Sensor (14k – 220M) | IFI EFS-5 S/N 213 | 1222605 | _____ |
| Electric Field Sensor (14k – 220M) | IFI EFS-5 S/N 132 | 1082157 | _____ |
| Isotropic Field Probe | AR FP2080 S/N300564 | 2017452 | _____ |
| Isotropic Field Probe | AR FP2080 S/N300467 | 2017451 | _____ |
| E-field Sensor (10k-1G) | AR FP5000S/N 28495 | 2015540 | _____ |

| | | |
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E-field Sensor (10k-1G)

AR FP5000S/N 28496 2015541

NASA MSFC EMI Test Facility (METF)

METF Test Equipment Calibration list

Date: _____

Project Name: _____

Sheet 2 of 4

| <u>Nomenclature:</u> | <u>Model</u> | <u>Cal ID</u> | <u>Cal Due Date</u> |
|---------------------------------|------------------------|---------------|---------------------|
| Digital Multimeter (rack mount) | 3455A | 676443 | _____ |
| Digital Multimeter (rack mount) | 3458A | 1153180 | _____ |
| Digital Multimeter (handheld) | Fluke 87 | M624653 | _____ |
| Digital Multimeter (handheld) | Fluke 867B | M636809 | _____ |
| Digital Multimeter (handheld) | Fluke 867B | M647219 | _____ |
| Digital Multimeter | Fluke 73 III | M648654 | _____ |
| Digital Multimeter | Fluke 73 III | M648781 | _____ |
| AC/DC Current Probe for DMM | Fluke i410 | M644165 | _____ |
| AC/DC Current Probe for DMM | Fluke i410 | M647219 | _____ |
| Digitizing Oscilloscope | Tek TDS 640A | 1962460 | _____ |
| Oscilloscope | Tek TDS 350 | M651061 | _____ |
| Digital Scope (handheld) | Tek THS720A | M651413 | _____ |
| Digital Scope (handheld) | Tek THS720A | 20174487 | _____ |
| Digital Scope (handheld) | Tek THS730A | | _____ |
| Microohm Meter | Keithley 580 | M651647 | _____ |
| Microohm Meter | Keithley 580 | 1218588 | _____ |
| DC Magnetic Gaussmeter | FW Bell 9640 | M651415 | _____ |
| DC Gaussmeter 3 Axis Probe | FW Bell S/N 303404 | M651414 | _____ |
| DC Magnetic Gaussmeter | FW Bell 9950 | 2015567 | _____ |
| DC Gaussmeter 3 Axis Probe | FW Bell S/N 294601 | M647993 | _____ |
| SSP30237 ISS LISN | 9238-10-TS-50 | M636920 | _____ |
| SSP30237 ISS LISN | 9238-10-TS-50 | M646547 | _____ |
| 521B LISN | MSFC | In-house cal | N/A |
| 521B LISN | MSFC | In-house cal | N/A |
| 521B LISN 30A | Solar 2122-4-TS-30-BNC | M648869 | _____ |
| 521B LISN | Solar 2123-4-TS-50-BNC | M650005 | _____ |
| 521B LISN | Solar 2123-4-TS-50-BNC | M648983 | _____ |
| 521B LISN | Solar 2122-4-TS-30-BNC | M650004 | _____ |
| Synthesizer/ Function Generator | HP 3325B | M651752 | _____ |
| Synthesizer/ Function Generator | HP 3325B | 1148596 | _____ |
| Synthesizer/ Function Generator | HP 83620B | 1895123 | _____ |
| Synthesizer/ Function Generator | HP 8341B | G84508 | _____ |
| Synthesizer/ Function Generator | HP 33120A | M651908 | _____ |
| Synthesizer/ Function Generator | AG E8257C | M651402 | _____ |
| Pre-Amplifier | HPT-PR18 | 2131485 | _____ |
| Pre-Amplifier | HPT-PR18 | 2131486 | _____ |

| | | |
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NASA MSFC EMI Test Facility (METF)

METF Test Equipment Calibration list

Date: _____ Project Name: _____ Sheet 3 of 4

| <u>Nomenclature:</u> | <u>Model</u> | <u>Cal ID</u> | <u>Cal Due Date</u> |
|-------------------------|-----------------------|---------------|---------------------|
| Power Meter Set #1 | Boonton 5232 | M651674 | _____ |
| Power Meter Set #2 | Boonton 5232 | 1965172 | _____ |
| Power Sensor Set #1 | Boonton 51011-EMC | M650451 | _____ |
| Power Sensor Set #1 | Boonton 51011-EMC | M650450 | _____ |
| Power Sensor Set #2 | Boonton 51011-EMC | M649236 | _____ |
| Power Sensor Set #2 | Boonton 51011-EMC | M649237 | _____ |
| RF Probe Set #1 | Boonton 952001B | M650453 | _____ |
| RF Probe Set #2 | Boonton 952001B | M652298 | _____ |
| Differential Probe | Tek P5205 SN: B018399 | M649623 | _____ |
| Differential Probe | Tek P5205 SN: B018346 | M649624 | _____ |
| Differential Probe | Tek P5205 SN: B017288 | M649436 | _____ |
| Differential Probe | Tek P5205 SN: B020810 | M652222 | _____ |
| RF Current Probe | Solar 6741-1 | M649672 | _____ |
| RF Current Probe | Solar 6741-1 | M650552 | _____ |
| RF Current Probe | Solar 6741-1 | M649609 | _____ |
| RF Injection Probe | Solar 9123-1N | M650517 | _____ |
| RF Injection Probe | Solar 9123-1N | M650518 | _____ |
| RF Current Probe | EMCO 91550-2 | M639667 | _____ |
| RF Injection Probe | EMCO 95236-1 | M643116 | _____ |
| High Voltage Attenuator | Solar 9410-1 | M650519 | _____ |
| High Voltage Attenuator | Solar 9410-1 | M650520 | _____ |
| COMB Generator | EMCO 4610 | M650931 | _____ |

| | | |
|--|-----------------|------------------------|
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5. DETAILED REQUIREMENTS

5.1 General.

This section specifies detailed emissions and susceptibility requirements and the associated test procedures. Table IV is a list of the specific requirements established by this standard identified by requirement number and title. General test procedures are included in this section. Specific test procedures are implemented by the Government approved EMITP. All results of tests performed to demonstrate compliance with the requirements are to be documented in the EMITR and forwarded to the Command or agency concerned for evaluation prior to acceptance of the equipment or subsystem. Design procedures and techniques for the control of EMI shall be described in the EMICP. Approval of design procedures and techniques described in the EMICP does not relieve the supplier of the responsibility of meeting the contractual emission, susceptibility, and design requirements.

5.1.1 Units of frequency domain measurements.

All frequency domain limits are expressed in terms of equivalent Root Mean Square (RMS) value of a sine wave as would be indicated by the output of a measurement receiver using peak envelope detection (see 4.3.10.1).

5.2 EMI control requirements versus intended installations.

Table V summarizes the requirements for equipment and subsystems intended to be installed in, on, or launched from various military platforms or installations. When an equipment or subsystem is to be installed in more than one type of platform or installation, it shall comply with the most stringent of the applicable requirements and limits. An "A" entry in the table means the requirement is applicable. An "L" entry means the applicability of the requirement is limited as specified in the appropriate requirement paragraphs of this standard; the limits are contained herein. An "S" entry means the procuring activity must specify the applicability, limit, and verification procedures in the procurement specification. Absence of an entry means the requirement is not applicable.

5.3 Emission and susceptibility requirements, limits, and test procedures.

Individual emission or susceptibility requirements and their associated limits and test procedures are grouped together in the following sections. The applicable frequency range and limit of many emission and susceptibility requirements varies depending on the particular platform or installation. The test procedures included in this section are valid for the entire frequency range specified in the procedure; however, testing only needs to be performed over the frequency range specified for the particular platform or installation.

| | | |
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TABLE IV. Emission and susceptibility requirements.

| Requirement | Description |
|-------------|---|
| CE101 | Conducted Emissions, Power Leads, 30 Hz to 10 kHz |
| CE102 | Conducted Emissions, Power Leads, 10 kHz to 10 MHz |
| CS101 | Conducted Susceptibility, Power Leads, 30 Hz to 150 kHz |
| CS114 | Conducted Susceptibility, Bulk Cable Injection, 10 kHz to 200 MHz |
| CS115 | Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation |
| CS116 | Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads, 10 kHz to 100 MHz |
| RE101 | Radiated Emissions, Magnetic Field, 30 Hz to 100 kHz |
| RE102 | Radiated Emissions, Electric Field, 10 kHz to 18 GHz |

| | | |
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TABLE V. Requirement matrix.

| Equipment and Subsystems Installed In, On, or Launched From the Following Platforms or Installations | Requirement Applicability | | | | | | | | | | | | | | | | |
|--|---------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | CE101 | CE102 | CE106 | CS101 | CS103 | CS104 | CS105 | CS109 | CS114 | CS115 | CS116 | RE101 | RE102 | RE103 | RS101 | RS103 | RS105 |
| Surface Ships | | A | L | A | S | S | S | | A | L | A | A | A | L | A | A | L |
| Submarines | A | A | L | A | S | S | S | L | A | L | A | A | A | L | A | A | L |
| Aircraft, Army, Including Flight Line | A | A | L | A | S | S | S | | A | A | A | A | A | L | A | A | L |
| Aircraft, Navy | L | A | L | A | S | S | S | | A | A | A | L | A | L | L | A | L |
| Aircraft, Air Force | | A | L | A | S | S | S | | A | A | A | | A | L | | A | |
| Space Systems, Including Launch Vehicles | | A | L | A | S | S | S | | A | A | A | | A | L | | A | |
| Ground, Army | | A | L | A | S | S | S | | A | A | A | | A | L | L | A | |
| Ground, Navy | | A | L | A | S | S | S | | A | A | A | | A | L | A | A | L |
| Ground, Air Force | | A | L | A | S | S | S | | A | A | A | | A | L | | A | |

Legend:

A: Applicable

L: Limited as specified in the individual sections of this standard

S: Procuring activity must specify in procurement documentation

| | | |
|--|-----------------|------------------------|
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5.4 CE101, conducted emissions, power leads, 30 Hz to 10 kHz.

5.4.1 CE101 applicability.

This requirement is applicable for power leads, including returns, that obtain power from other sources not part of the EUT for submarines, Army aircraft[&] (including flight line) and Navy aircraft^{*&}

*For equipment intended to be installed on Navy aircraft, this requirement is applicable only for aircraft with Anti-Submarine Warfare (ASW) capability.

[&]For AC applications, this requirement is applicable starting at the second harmonic of the EUT power frequency.

5.4.2 CE101 limits.

Conducted emissions on power leads shall not exceed the applicable values shown on Figures CE101-1 through CE101-3, as appropriate, for submarines and Figure CE101-4 for Army aircraft (including flight line) and Navy ASW aircraft.

5.4.3 CE101 test procedure.

5.4.3.1 Purpose.

This test procedure is used to verify that electromagnetic emissions from the EUT do not exceed the specified requirements for power input leads including returns.

5.4.3.2 Test equipment.

The test equipment shall be as follows:

Table CE101-1. METF CE102 Equipment.

| Item | METF Equipment | Serial # | Calibration ID | Calibration Due Date |
|-----------------------|--|----------|----------------|----------------------|
| Measurement receiver | Rohde&Schwarz ESI measurement receiver, 20Hz-26.5GHz | | | |
| Current probe | Electro-Metrics PCL-10 current probe, 20Hz-100kHz | | | |
| Data recording device | Personal computer functioning as data recording device | N/A | N/A | N/A |
| Signal Generator | HP 33120A, 0.1mHz-15MHz, or equivalent | | | |
| Oscilloscope | Tektronix THS720A, 100MHz | | | |

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| Item | METF Equipment | Serial # | Calibration ID | Calibration Due Date |
|---------------------------|---|----------|----------------|----------------------|
| Probe calibration fixture | Solar Type 9251-1, 20Hz-500MHz | | N/A | N/A |
| Resistor | 50 ohm coaxial load | N/A | N/A | N/A |
| LISN (Positive Lead) | Solar MIL-STD-461E LISN Model # _____ | | | |
| LISN (Return Lead) | Solar MIL-STD-461E LISN Model # _____ | | | |
| Test Software | | N/A | N/A | N/A |

5.4.3.3 Setup.

The test setup shall be as follows:

- a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and 4.3.8. The LISN may be removed or replaced with an alternative stabilization device when approved by the procuring activity.
- b. Calibration.
 - (1) Configure the test setup for the measurement system check as shown in Figure CE101-5.
 - (2) Connect the Rohde & Schwarz measurement receiver to the current probe using FSJ4 coax cable.
 - (3) Record any deviation from the standard CE101 setup on CE101 deviation page(s) as needed.
- c. EUT testing.
 - (1) Configure the test setup for compliance testing of the EUT as shown in Figure CE101-6.
 - (2) Connect the Rohde & Schwarz measurement receiver to the current probe the using FSJ4 coax cable.
 - (3) Position the current probe 5 cm from the LISN.
 - (4) Record any deviation from the standard CE101 setup on CE101 deviation page(s) as needed.

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5.4.3.4 Procedures.

The test procedures shall be as follows:

- a. Turn on the measurement equipment and allow a sufficient time for stabilization.
- b. Calibration. Evaluate the overall measurement system from the current probe to the data output device.
 - (1) Ensure that the appropriate correction factors for the current probe and FSJ4 cable are in the Rohde & Schwarz CE101 scan table.
 - (2) Apply a calibrated signal level, which is at least 6 dB below the applicable limit at 1 kHz, 3 kHz, and 10 kHz, to the current probe. Ensure signal generator output is in Vrms.
 - (3) Verify the current level, using the oscilloscope and load resistor; also, verify that the current waveform is sinusoidal. Ensure oscilloscope input is set to 1X probe.
 - (4) Scan the measurement receiver for each frequency in the same manner as a normal data scan. Pause the Rohde & Schwarz control software at appropriate points to enable changing the signal generator frequency and amplitude. Verify that the measurement receiver indicates a level within ± 3 dB of the injected level.
 - (5) Record the measured level in column 6 of table CE101-2.
 - (6) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.
 - (7) Record any deviations from the standard CE101 calibration procedure on CE101 deviation page(s) as needed.

Table CE101-2. Calibration Levels

| Frequency (Hz) | MIL-STD-461E 28Vdc Limit Level (dB μ A) | Limit Level -6dB (dB μ A) | Signal Injection Level (Vrms) | METF Target Level (dB μ A) | Measured Value (dB μ A) |
|-------------------|--|-------------------------------------|--|--------------------------------------|-----------------------------------|
| 1k | 100 | 94 | 2.5 on scope | 94 | |
| 3k | 90.5 | 84.5 | 0.84 on scope | 84.5 | |
| 10k | 80 | 74 | 0.25 on scope | 74 | |

| | | |
|--|-----------------|------------------------|
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- c. EUT testing. Determine the conducted emissions from the EUT input power leads, including returns. Perform emission data scans using the measurement setup of Figure CE101-6.
 - (1) Turn on the EUT and allow sufficient time for stabilization.
 - (2) Select an appropriate lead for testing and clamp the current probe into position.
 - (3) Scan the measurement receiver over the applicable frequency range, using the bandwidths and minimum measurement times specified in Table II.
 - (4) Repeat 5.4.3.4c(3) for each power lead.
 - (5) Record any deviations from the standard CE101 EUT test procedure on CE101 deviation page(s) as needed.

5.4.3.5 Data presentation.

Data presentation shall be as follows:

- a. Continuously and automatically plot amplitude versus frequency profiles on X-Y axis outputs. Manually gathered data is not acceptable except for plot verification.
- b. Display the applicable limit on each plot.
- c. Provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less stringent, and a minimum amplitude resolution of 1 dB for each plot.
- d. Provide plots for both the measurement and system check portions of the procedure.
- e. Record results in Table CE101-3.

| | | |
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EUT:_____

| Cable Under Test | Pass/Fail | Data Plot Number | Overlimit Amplitudes and Frequencies | EUT Configuration |
|------------------|-----------|------------------|--------------------------------------|-------------------|
| | | | | |
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Table CE101-3. CE101 Test Results

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|--|-----------------|------------------------|
| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
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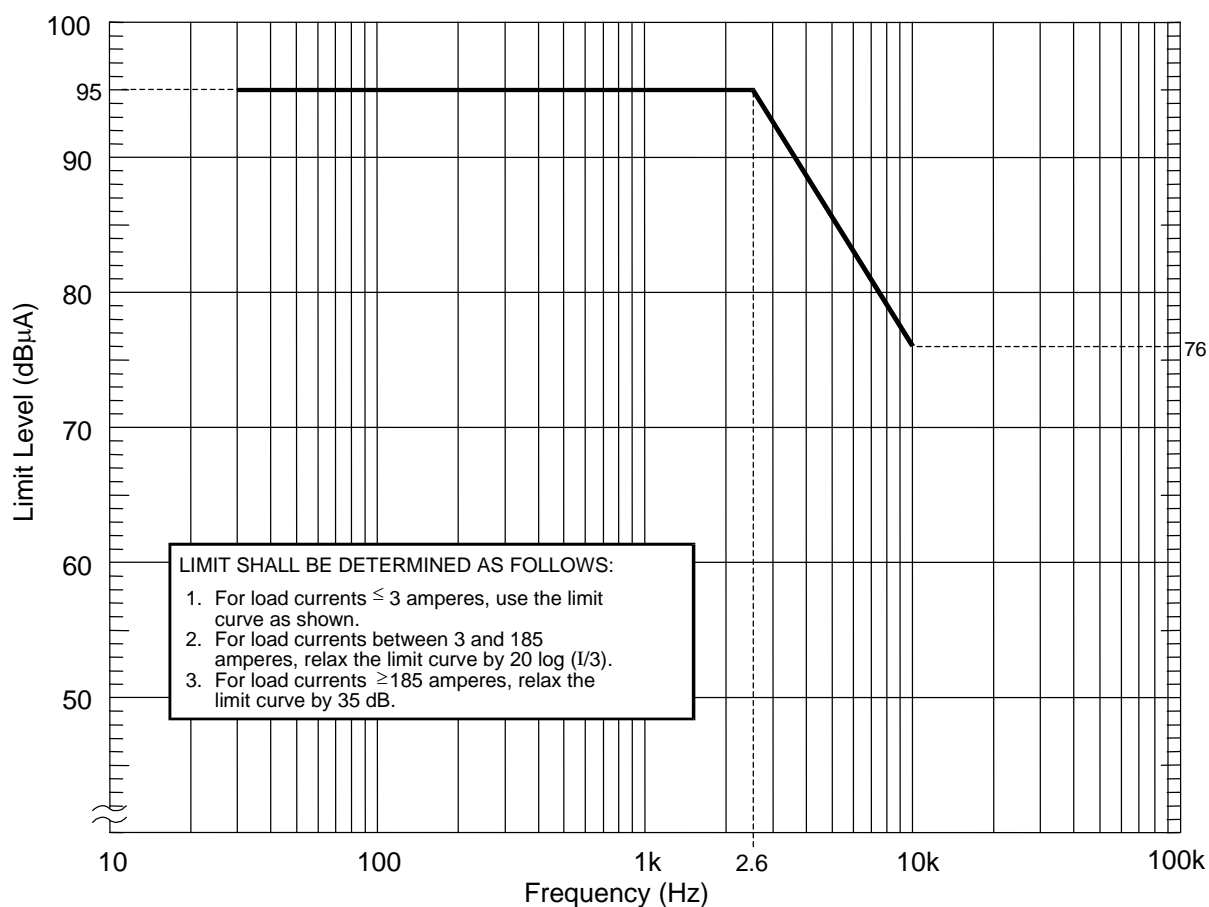
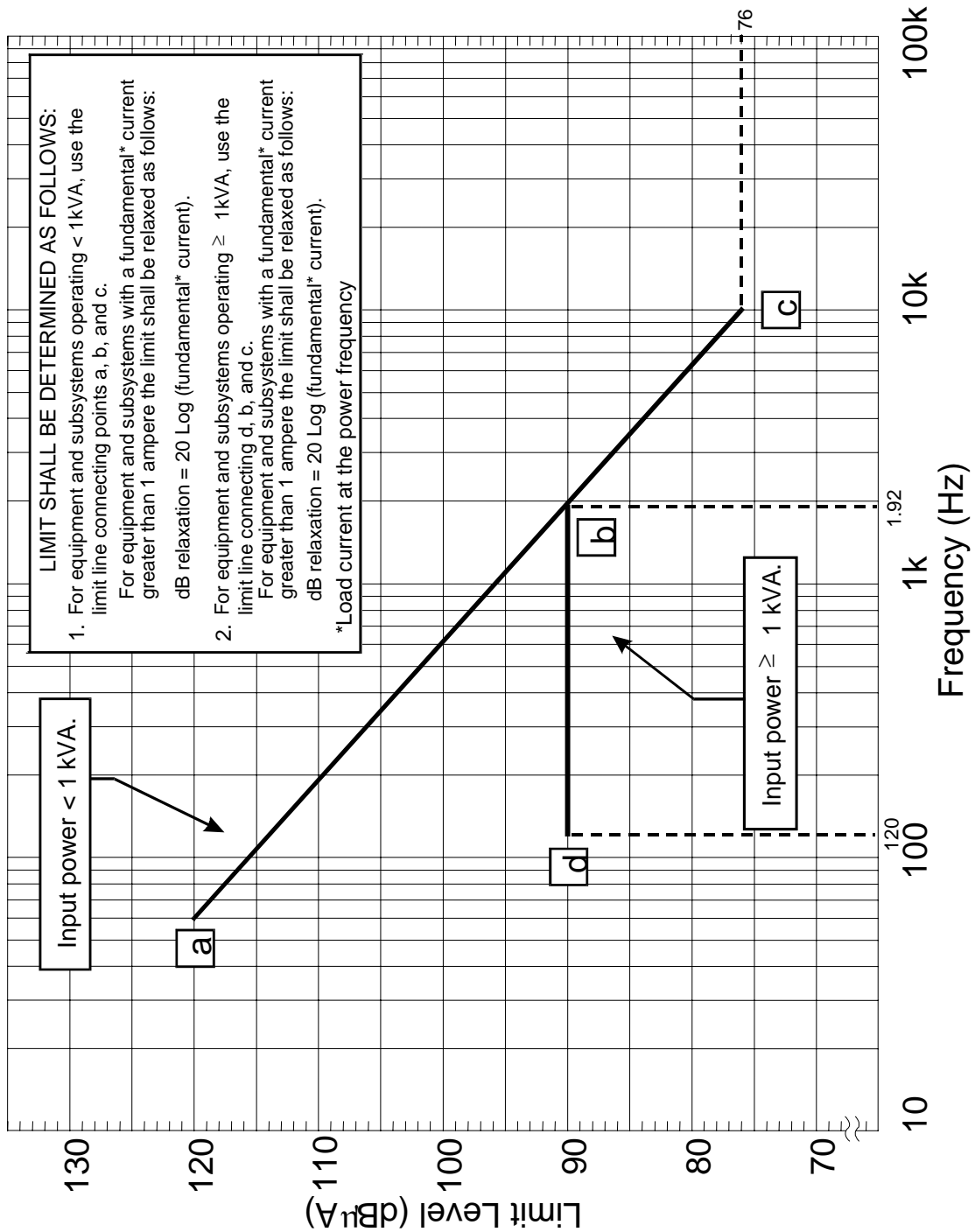
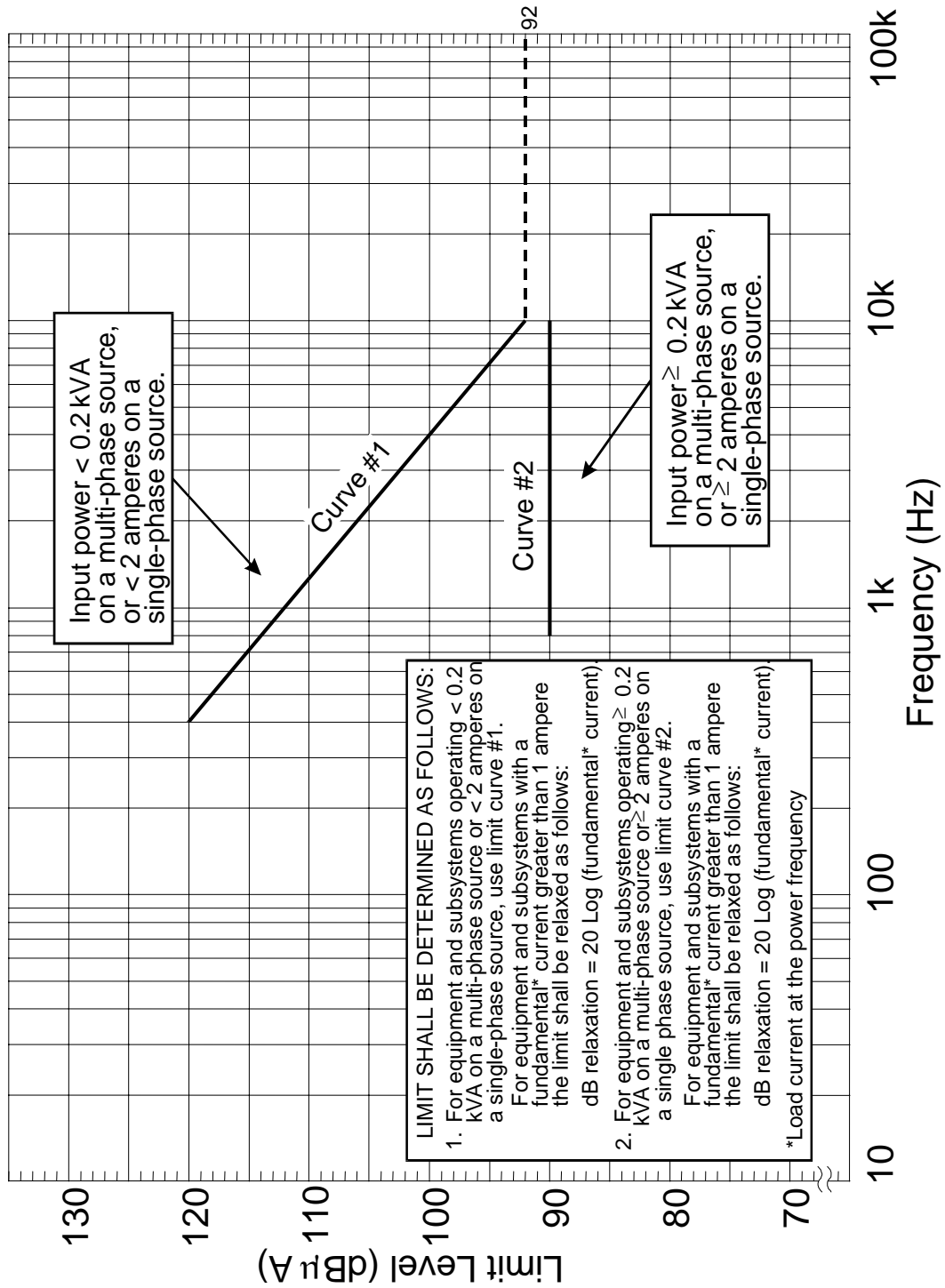


FIGURE CE101-1. CE101 limit for submarine applications, DC.



| | | |
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FIGURE CE101-2. CE101 limit for submarine applications, 60 Hz.



| | | |
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FIGURE CE101-3. CE101 limit for submarine applications, 400 Hz.

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|--|-----------------|------------------------|
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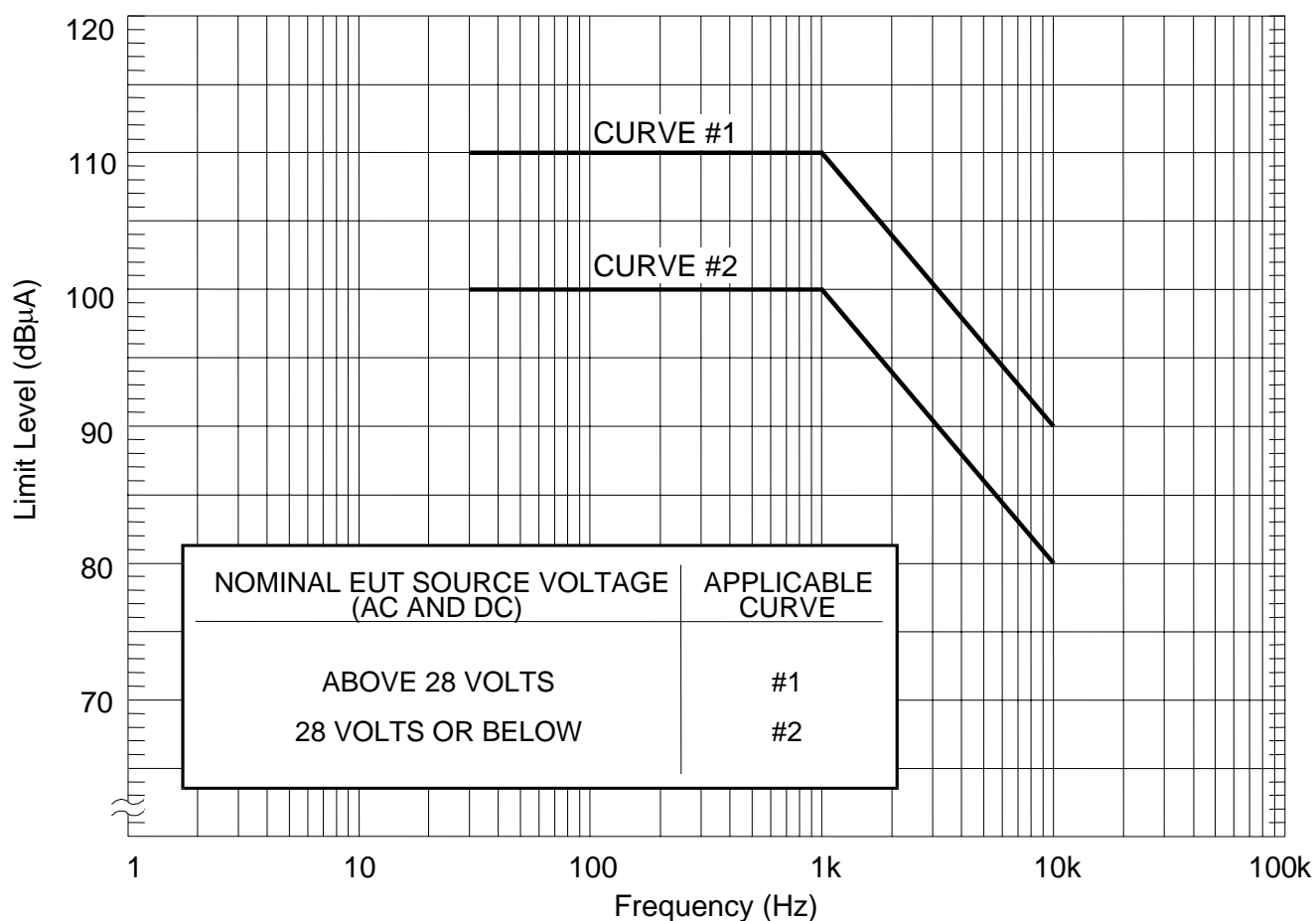


FIGURE CE101-4. CE101 limit for Navy ASW aircraft and Army aircraft (including flight line) applications.

CE101

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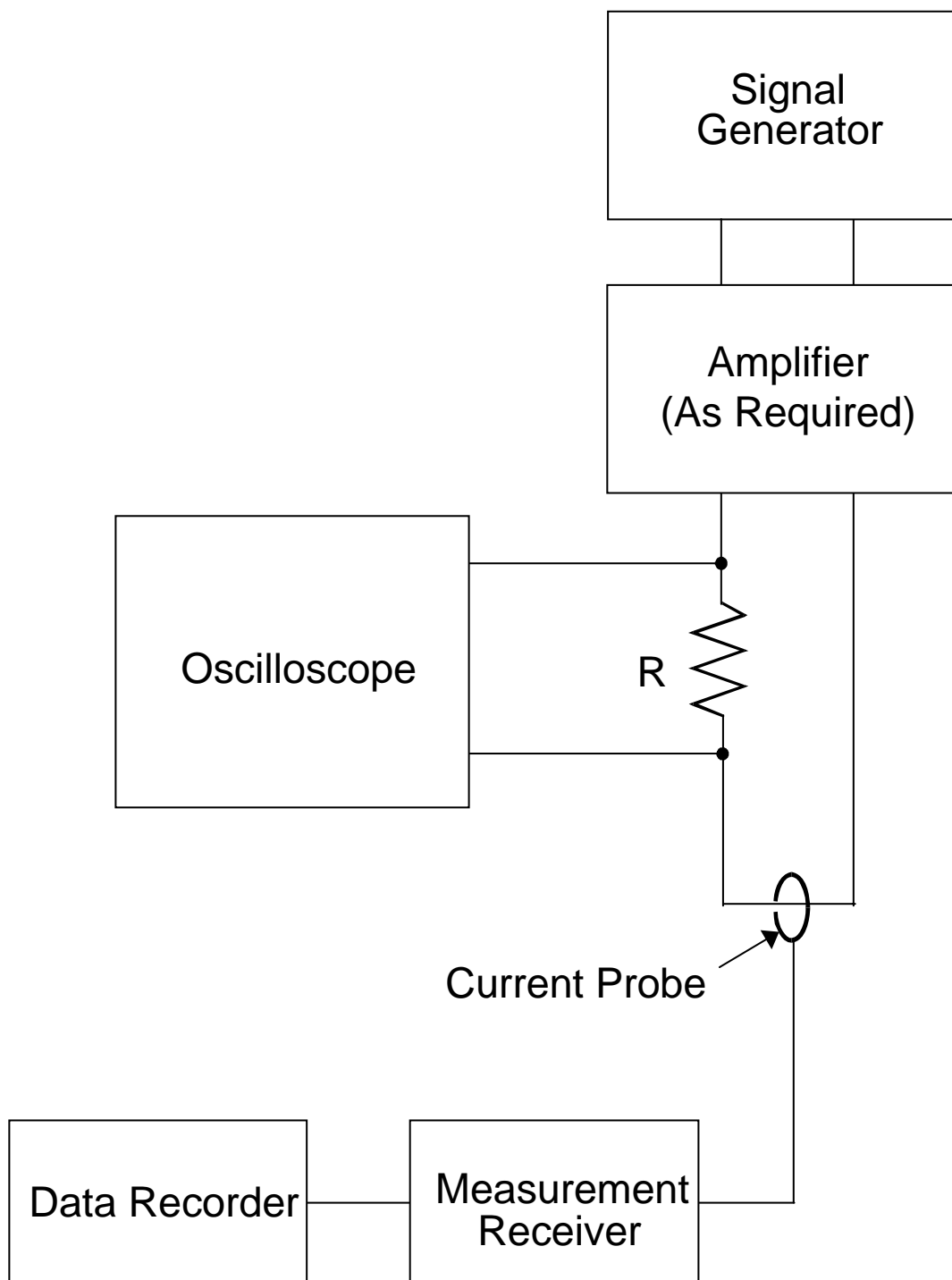
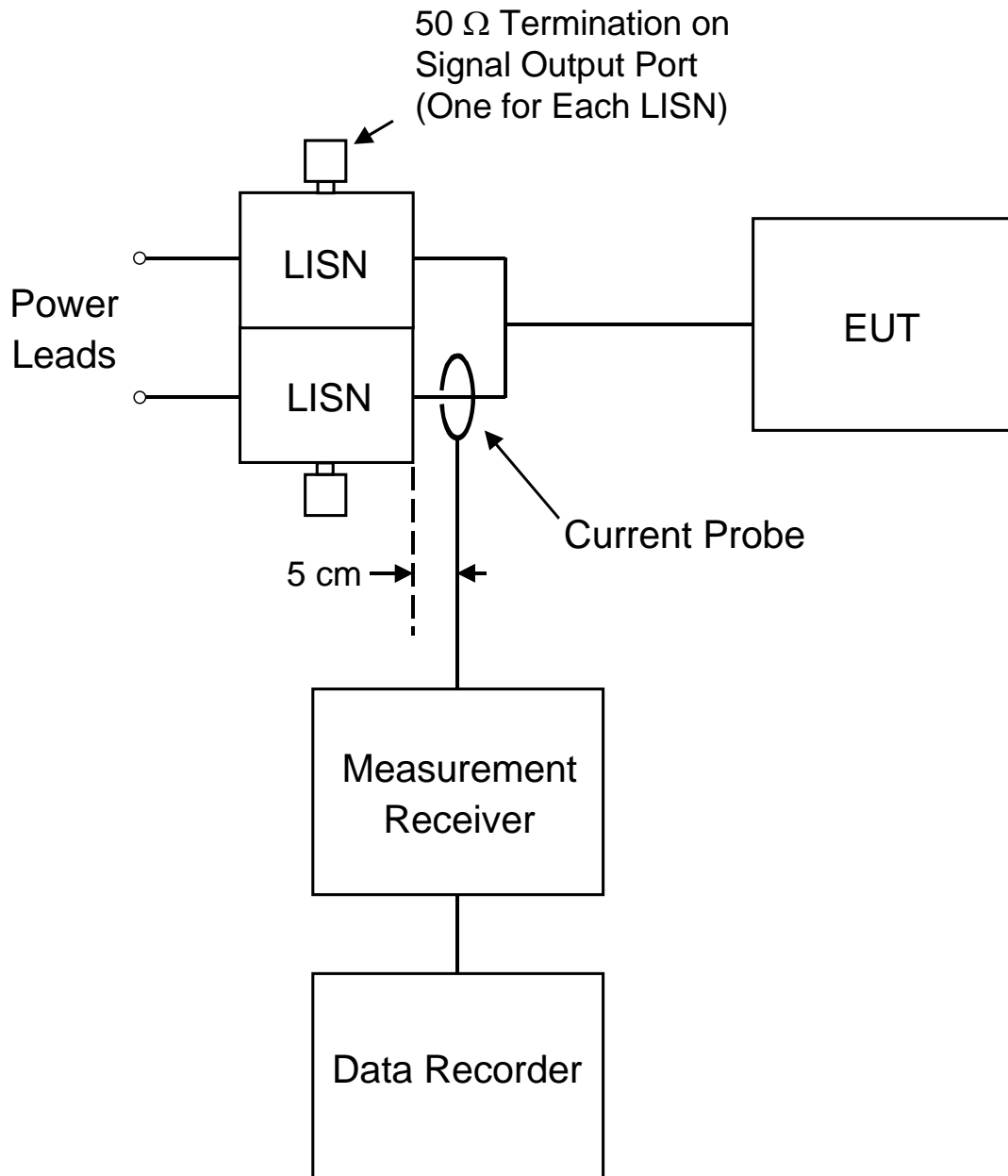


FIGURE CE101-5. Measurement system check.

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| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
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|--|-----------------|------------------------|
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5.5 CE102, conducted emissions, power leads, 10 kHz to 10 MHz.

5.5.1 CE102 applicability.

This requirement is applicable from 10 kHz to 10 MHz for all power leads, including returns, that obtain power from other sources not part of the EUT.

5.5.2 CE102 limits.

Conducted emissions on power leads shall not exceed the applicable values shown on Figure CE102-1.

5.5.3 CE102 test procedure.

5.5.3.1 Purpose.

This test procedure is used to verify that electromagnetic emissions from the EUT do not exceed the specified requirements for power input leads, including returns.

5.5.3.2 Test equipment.

The test equipment shall be as follows:

Table CE102-1. METF CE102 Equipment.

| Item | METF Equipment | Serial # | Calibration ID | Calibration Due Date |
|--------------------------|--|----------|----------------|----------------------|
| Measurement receiver | Rohde&Schwarz ESI measurement receiver, 20Hz-26.5GHz | | | |
| Data recording device | Personal computer functioning as data recording device | N/A | N/A | N/A |
| Signal Generator | HP 3325B, 20Hz-20MHz, or equivalent | | | |
| Attenuator, 20dB, 50 ohm | Attenuator, 20dB, 50 ohm | N/A | N/A | N/A |
| Oscilloscope | Tektronix THS720A, 100MHz | | | |
| LISN (Positive Lead) | Solar MIL-STD-461E LISN Model # _____ | | | |
| LISN (Return Lead) | Solar MIL-STD-461E LISN Model # _____ | | | |
| Test Software | | N/A | N/A | N/A |

| | | |
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| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
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5.5.3.3 Setup.

The test setup shall be as follows:

- a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and 4.3.8.
- b. Calibration.
 - (1) Configure the test setup for the measurement system check as shown in Figure CE102-2. Ensure that the EUT power source is turned off.
 - (2) Connect the Rhode & Schwarz measurement receiver to the 20 dB attenuator.
 - (3) Connect the 20 dB attenuator to the “EMI meter” port of the LISN using FSJ4 coax cable.
 - (4) Record any deviation from the standard CE102 setup on CE102 deviation page(s) as needed.
- c. EUT testing.
 - (1) Configure the test setup for compliance testing of the EUT as shown in Figure CE102-3.
 - (2) Connect the Rhode & Schwarz measurement receiver to the 20 dB attenuator.
 - (3) Connect the 20 dB attenuator to the “EMI meter” port of the LISN using FSJ4 coax cable.
 - (4) Record any deviation from the standard CE102 setup on CE102 deviation page(s) as needed.

5.5.3.4 Procedures.

The test procedures shall be as follows:

- a. Calibration. Perform the measurement system check using the measurement system check setup of Figure CE102-2.
 - (1) Turn on the measurement equipment and allow a sufficient time for stabilization.
 - (2) Ensure that the appropriate correction factors for the LISN coupling capacitor, FSJ4 cable, and 20 dB attenuator are in the Rhode and Schwarz CE102 scan table
 - (3) Apply a signal level that is at least 6 dB below the limit at 10 kHz, 100 kHz, 2 MHz and 10 MHz to the power output terminal of the LISN. Ensure signal

CE102

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|--|-----------------|------------------------|
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generator output is in Vrms and is sinusoidal. At 10 kHz and 100 kHz, use an oscilloscope to measure the signal level and verify that it is sinusoidal. Ensure oscilloscope input is set to 1X probe. At 2 MHz and 10 MHz, use a calibrated output level directly from a 50 Ω signal generator. Use the values in table CE102-1 to perform the calibration.

Table CE102-2. Calibration Levels

| Frequency (Hz) | MIL-STD-461E 28Vdc Limit Level (dB μ V) | Limit Level -6dB (dB μ V) | Signal Injection Level (mVrms) | METF Target Level (dB μ V) | Measured Value (dB μ V) |
|-------------------|--|-------------------------------------|---|--------------------------------------|-----------------------------------|
| 10k | 94 | 88 | 22.4 on scope | 88 | |
| 100k | 74 | 68 | 2.0 on scope | 68 | |
| 2M | 60 | 54 | 0.45 on signal generator | 54 | |
| 10M | 60 | 54 | 0.45 on signal generator | 54 | |

- (4) Scan the measurement receiver for each frequency in the same manner as a normal data scan. Pause the Rhode & Schwarz control software at appropriate points to enable changing the HP3325B signal generator frequency and amplitude. Verify that the measurement receiver indicates a level within ± 3 dB of the injected level.
 - (5) Record the measured level in column 6 of table CE102-2.
 - (6) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.
 - (7) Repeat 5.5.3.4a(2) through 5.5.3.4a(4) for each LISN.
 - (8) Record any deviations from the standard CE102 calibration procedure on CE102 deviation page(s) as needed.
- b. EUT testing. Perform emission data scans using the measurement setup of Figure CE102-3.
- (1) Turn on the EUT and allow a sufficient time for stabilization.

| | | |
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- (2) Select an appropriate lead for testing.
- (3) Scan the measurement receiver over the applicable frequency range, using the bandwidths and minimum measurement times in the Table II.
- (4) Repeat 5.5.3.4b(2) and 5.5.3.4b(3) for each power lead.
- (5) Record any deviations from the standard CE102 EUT test procedure on CE102 deviation page(s) as needed.

5.5.3.5 Data presentation.

Data presentation shall be as follows:

- a. Continuously and automatically plot amplitude versus frequency profiles on X-Y axis outputs. Manually gathered data is not acceptable except for plot verification.
- b. Display the applicable limit on each plot.
- c. Provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less stringent, and a minimum amplitude resolution of 1 dB for each plot.
- d. Provide plots for both the measurement system check and measurement portions of the procedure.
- e. Record results in Table CE102-3.

| | | |
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EUT:_____

| Cable Under Test | Pass/Fail | Data Plot Number | Overlimit Amplitudes and Frequencies | EUT Configuration |
|------------------|-----------|------------------|--------------------------------------|-------------------|
| | | | | |
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Table CE102-3. CE102 Test Results

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|--|-----------------|------------------------|
| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
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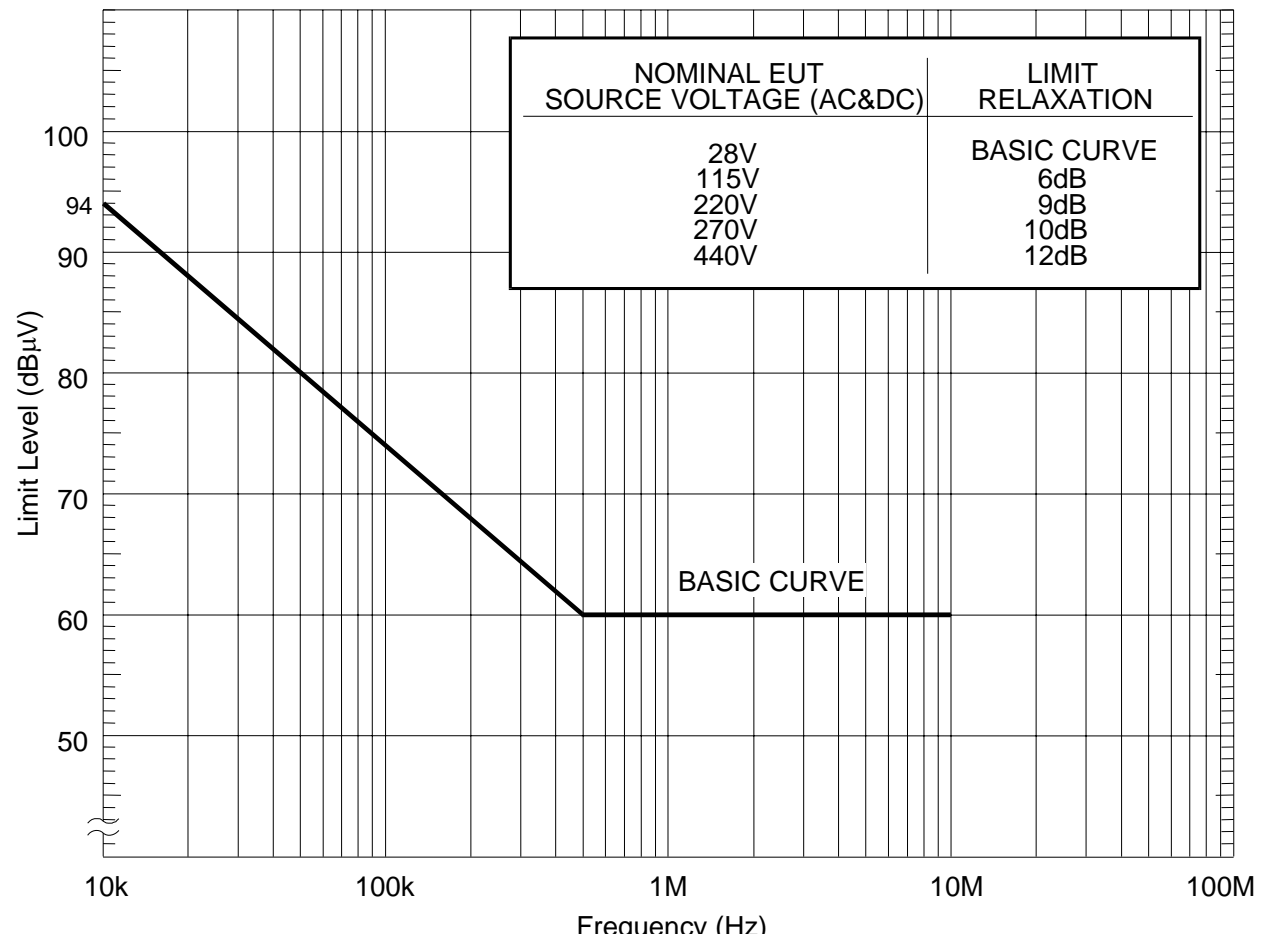


FIGURE CE102-1. CE102 limit (EUT power leads, AC and DC) for all applications.

| | | |
|--|-----------------|------------------------|
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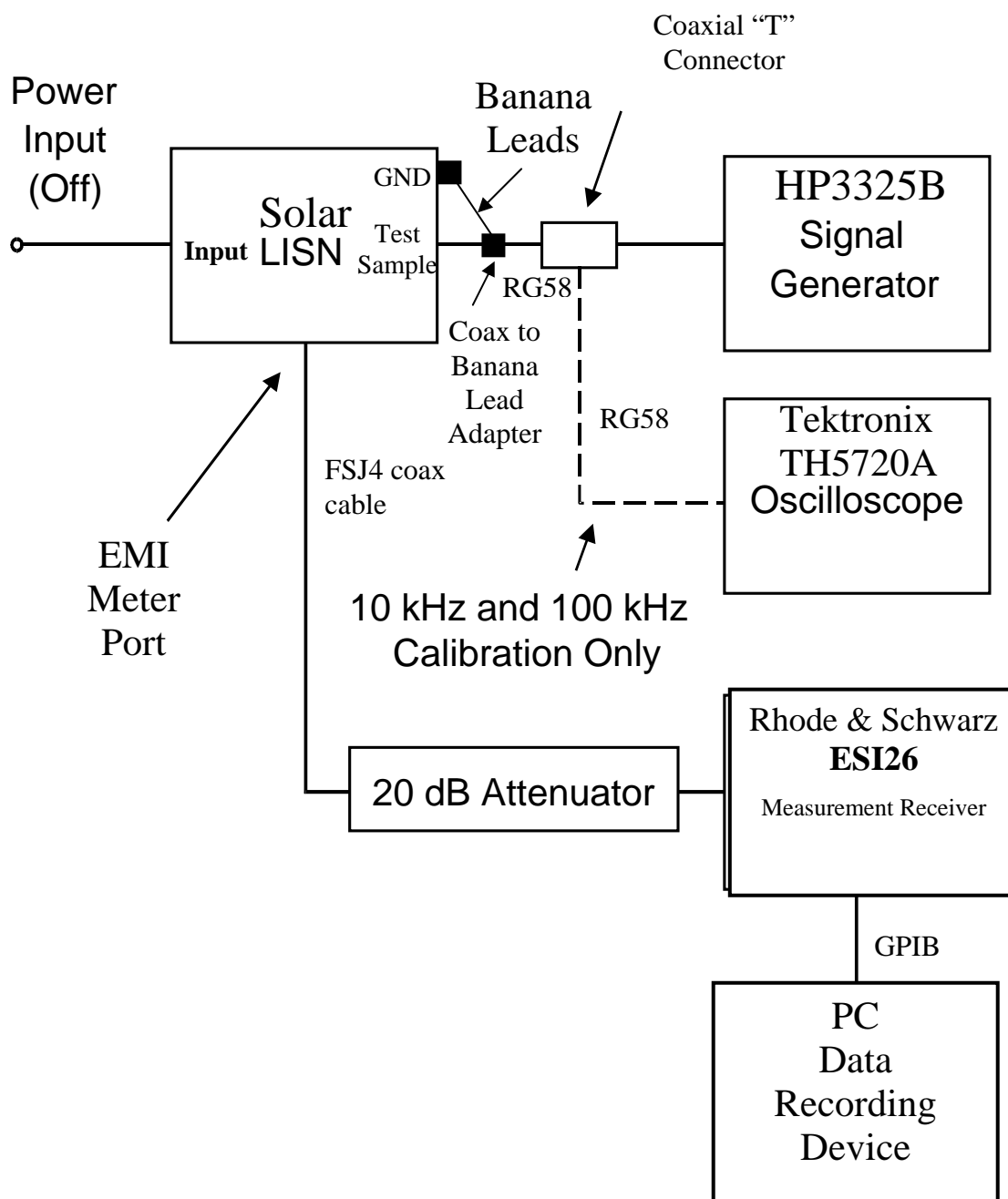


FIGURE CE102-2. Measurement system check setup.

| | | |
|--|-----------------|------------------------|
| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
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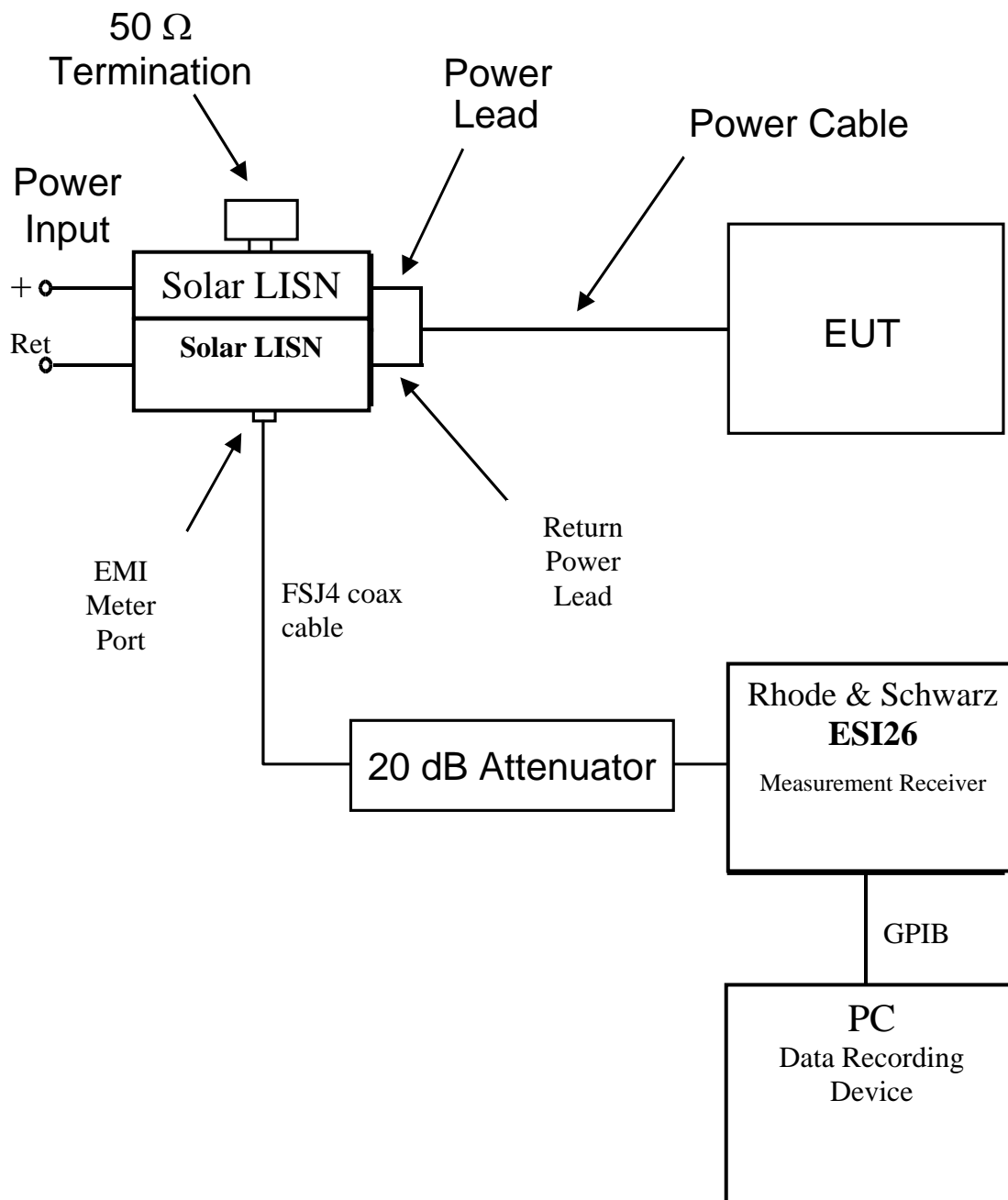


FIGURE CE102-3. Measurement setup.

| | | |
|--|-----------------|------------------------|
| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
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5.7 CS101, conducted susceptibility, power leads, 30 Hz to 150 kHz.

5.7.1 CS101 applicability.

This requirement is applicable to equipment and subsystem AC and DC input power leads, not including returns. If the EUT is DC operated, this requirement is applicable over the frequency range of 30 Hz to 150 kHz. If the EUT is AC operated, this requirement is applicable starting from the second harmonic of the EUT power frequency and extending to 150 kHz.

5.7.2 CS101 limit.

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to a test signal with voltage levels as specified in Figure CS101-1.

The requirement is also met when the power source is adjusted to dissipate the power level shown in Figure CS101-2 in a 0.5 ohm load and the EUT is not susceptible.

5.7.3 CS101 test procedure.

5.7.3.1 Purpose.

This test procedure is used to verify the ability of the EUT to withstand signals coupled onto input power leads.

5.7.3.2 Test equipment.

The test equipment shall be as follows:

Table CS101-1. METF CS101 Equipment.

| Item | METF Equipment | Serial # | Calibration ID | Calibration Due Date |
|----------------------|--|----------|----------------|----------------------|
| Signal generator | HP3325B, 30Hz-20MHz, or equivalent | | | |
| Power amplifier | Techron 752 power amplifier, 20Hz-25kHz, 144W, or equivalent | | N/A | N/A |
| Oscilloscope | Tektronix THS720A, 100MHz | | | |
| Coupling transformer | Solar Type 6220-1A coupling transformer, 30Hz-250kHz, 50A dc | | N/A | N/A |
| Capacitor, 10uF | Capacitor, 10uF | N/A | N/A | N/A |
| Resistor, 0.5 ohm | Dale RH-250 250W resistor, 0.5 ohm (2 1 ohm resistors in parallel) | N/A | N/A | N/A |
| | | | | |

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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| Item | METF Equipment | Serial # | Calibration ID | Calibration Due Date |
|----------------------------|--|----------|----------------|----------------------|
| LISN (Positive Lead) | Solar MIL-STD-461E LISN Model # _____ | | | |
| LISN (Return Lead) | Solar MIL-STD-461E LISN Model # _____ | | | |
| Test Software | | N/A | N/A | N/A |
| Voltmeter | HP3458A digital multimeter, or equivalent | | | |
| Video monitoring camera | EMC Automation VC-04 video camera, controller, and monitor | N/A | N/A | N/A |

5.7.3.3 Setup.

The test setup shall be as follows:

- a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and 4.3.8.
- b. Calibration. Configure the test equipment in accordance with Figure CS101-3. Set up the oscilloscope, HP3458A and AETA CS101 software to monitor the voltage across the 0.5 ohm resistor.
- c. Trial run on calibration resistor. Configure the test equipment in accordance with Figure CS101-3. Set up the oscilloscope, HP3458A, and AETA CS101 software to monitor the voltage across the 0.5 ohm resistor.
- d. EUT testing.
 - (1) For DC or single phase AC power, configure the test equipment as shown in Figure CS101-4.
 - (2) For three phase ungrounded power, configure the test setup as shown in Figure CS101-5.
 - (3) For three phase wye power (four power leads), configure the test setup as shown in Figure CS101-6.
- e. Record any deviations from the CS101 calibration or EUT test setup on CS101

| | | |
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deviation sheet(s) as needed.

5.7.3.4 Procedures.

The test procedures shall be as follows:

- a. Turn on the measurement equipment and allow sufficient time for stabilization.
- b. Calibration.
 - (1) Configure AETA to set the signal generator to the lowest test frequency..
 - (2) Increase the applied signal until the oscilloscope and the HP3458A indicates the voltage level corresponding to the maximum required power level specified for the limit. Verify the output waveform is sinusoidal on the oscilloscope.
 - (3) AETA will record the setting of the signal source for this power level.
 - (4) Scan the required frequency range for testing and record the signal source setting needed to maintain the required power level in Figure CS101-2..
- c. Trial run on calibration resistor to confirm test setup is correct, applied voltage level is correct, and waveform is sinusoidal.
 - (1) Configure AETA software for a CS101 run with the same parameters as for an EUT run (amplitude, frequency step size, etc.)
 - (2) Perform a CS101 run on the calibration resistor. Closely monitor the oscilloscope screen, using the remote control camera, to ensure the correct voltage is applied at each frequency and that the waveform is sinusoidal.
 - (3) If the oscilloscope does not agree with the AETA output, stop and determine the source of the problem. Correct the problem before continuing to EUT testing.
- d. EUT Testing.
 - (1) Turn on the EUT and allow sufficient time for stabilization.
 - (2) Configure AETA to set the signal generator to the lowest test frequency. Increase the signal level until the required voltage or power level is reached on the power lead. (Note: Power is limited to the level calibrated in 5.7.3.4b(2).)
 - (3) While maintaining at least the required signal level, scan through the required frequency range at a rate no greater than specified in Table III.
 - (4) Closely monitor the oscilloscope screen, using the remote control camera, to ensure that the CS101 voltage limit is not exceeded. If the voltage is exceeded at any frequency, immediately stop AETA and determine the source of the problem.
 - (5) Susceptibility evaluation.
 - (a) Monitor the EUT for degradation of performance.

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- (b) If susceptibility is noted, determine the threshold level in accordance with 4.3.10.4.3 and verify that it is above the limit.
- (5) Repeat 5.7.3.4c(2) through 5.7.3.4c(4) for each power lead, as required. For three phase ungrounded power, the measurements shall be made according to the following table:

| Coupling Transformer in Line | Voltage Measurement From |
|---------------------------------|-----------------------------|
| A | A to B |
| B | B to C |
| C | C to A |

For three phase wye power (four leads) the measurements shall be made according to the following table:

| Coupling Transformer in Line | Voltage Measurement From |
|---------------------------------|-----------------------------|
| A | A to neutral |
| B | B to neutral |
| C | C to neutral |

5.7.3.5. Data presentation.

Data presentation shall be as follows:

- Provide graphical or tabular data showing the frequencies and amplitude from the calibration run.
- Provide graphical or tabular data showing the frequencies and amplitudes at which the test was conducted for each lead, using Table CS101-1.
- Provide data on any susceptibility thresholds and the associated frequencies that were determined for each power lead, using Table CS101-1.
- Provide indications of compliance with the applicable requirements for the susceptibility evaluation specified in 5.7.3.4c for each lead, using Table CS101-1.
- Record any deviations from the standard CS101 calibration or EUT test procedures on CS101 deviation sheet(s) as needed.

| | | |
|--|-----------------|------------------------|
| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
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EUT: _____

| Cable Under Test | Pass/Effect | Observed Effect(s) | Threshold Level(s) |
|------------------|-------------|--------------------|--------------------|
| | | | |
| | | | |
| | | | |
| | | | |

Table CS101-1. CS101 Test Results

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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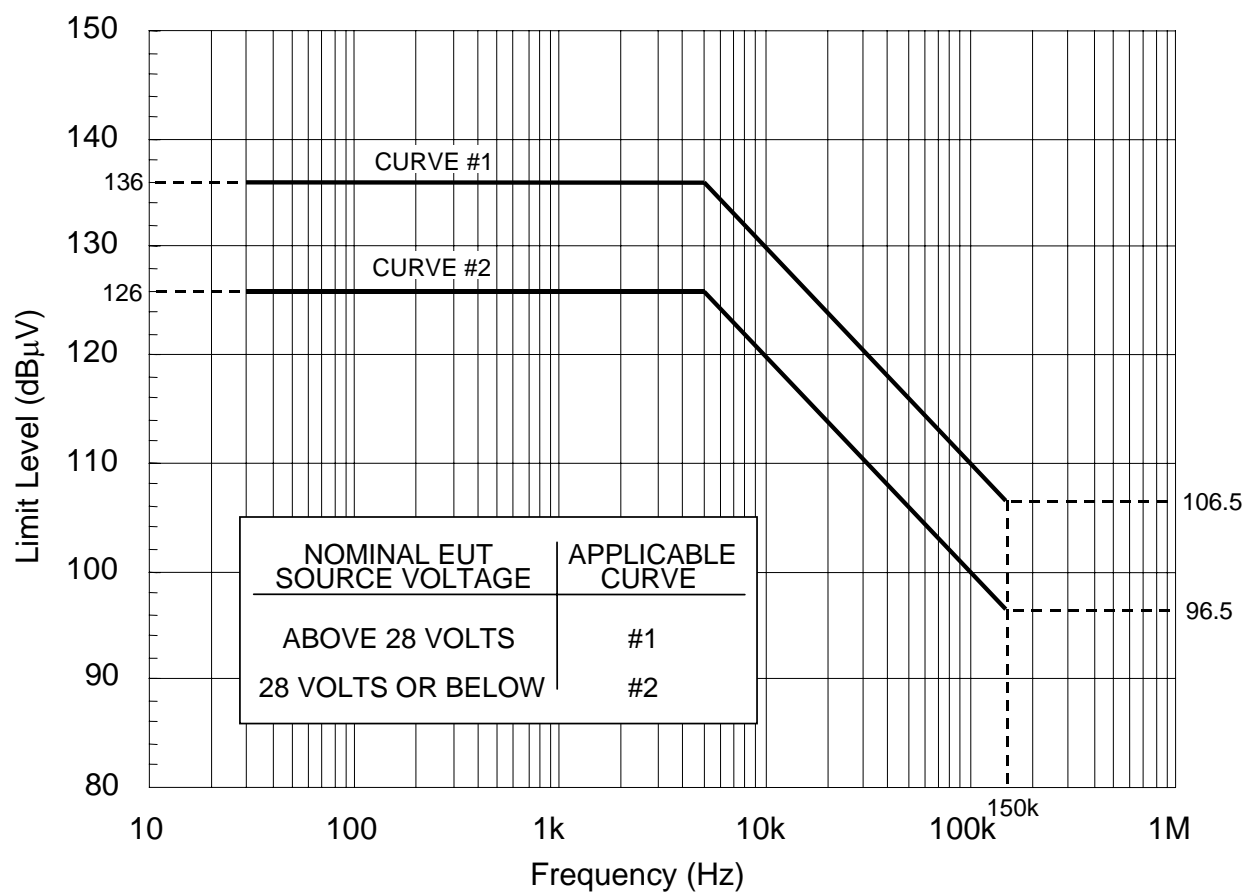


FIGURE CS101-1. CS101 voltage limit for all applications.

CS101

| | | |
|--|-----------------|------------------------|
| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
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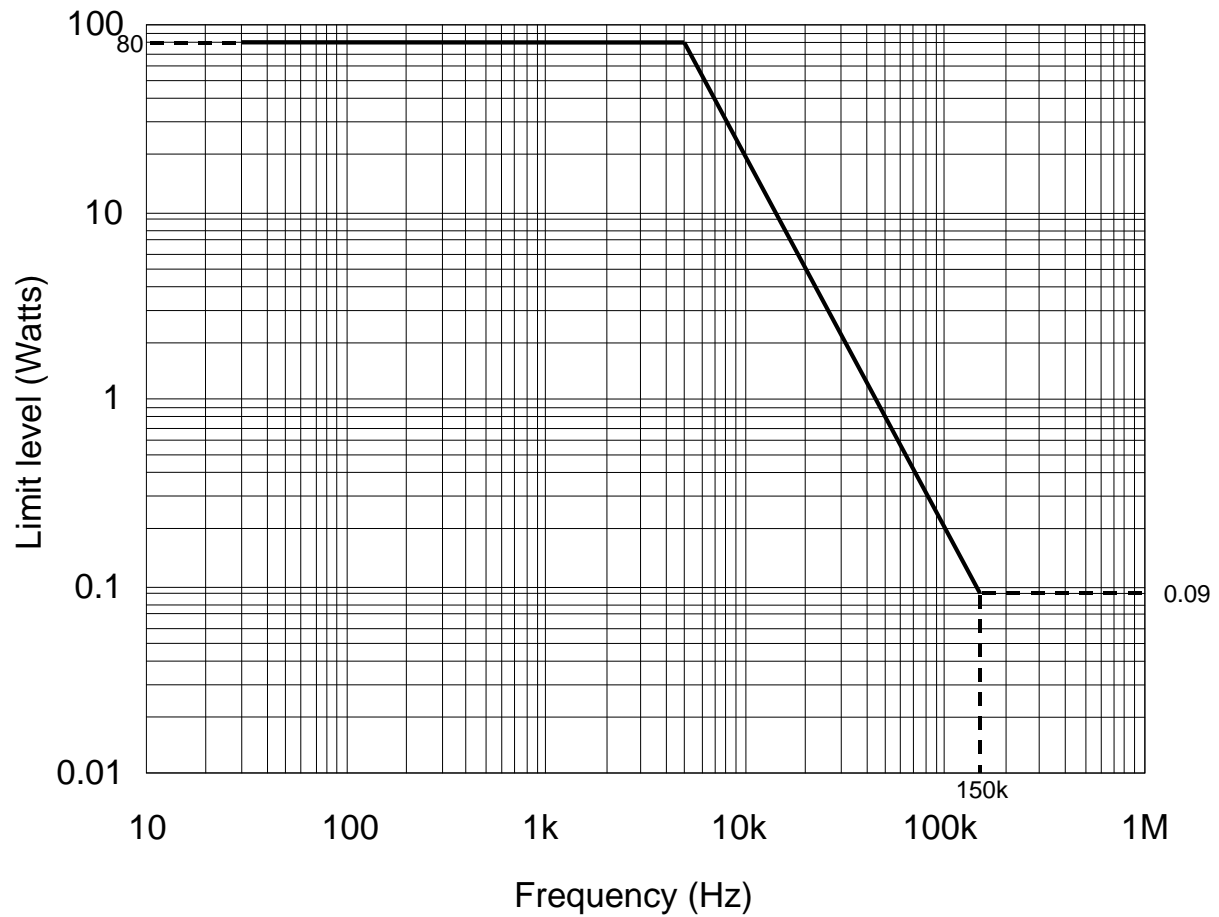


FIGURE CS101-2. CS101 power limit for all applications.

CS101

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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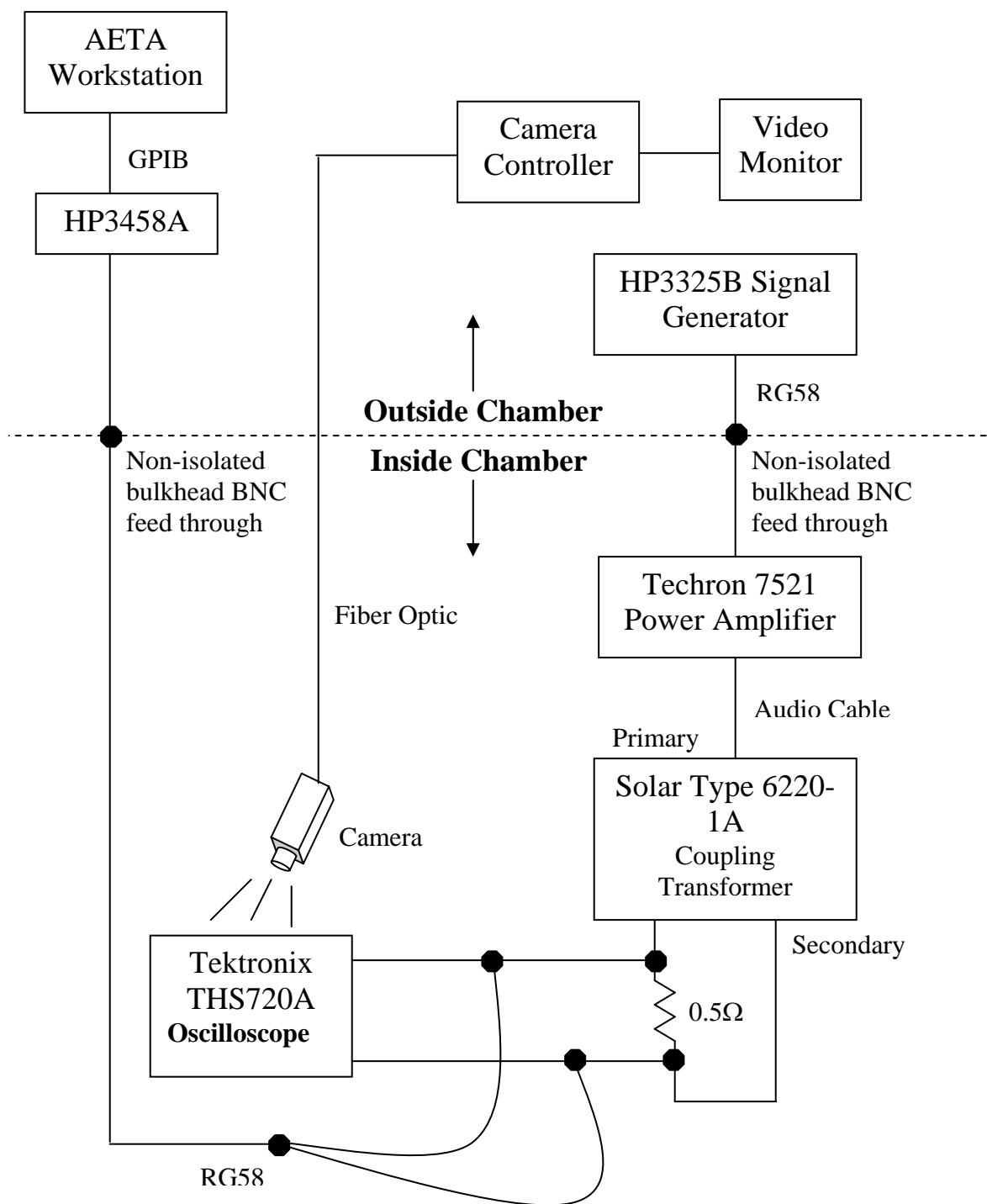


FIGURE CS101-3. Calibration.

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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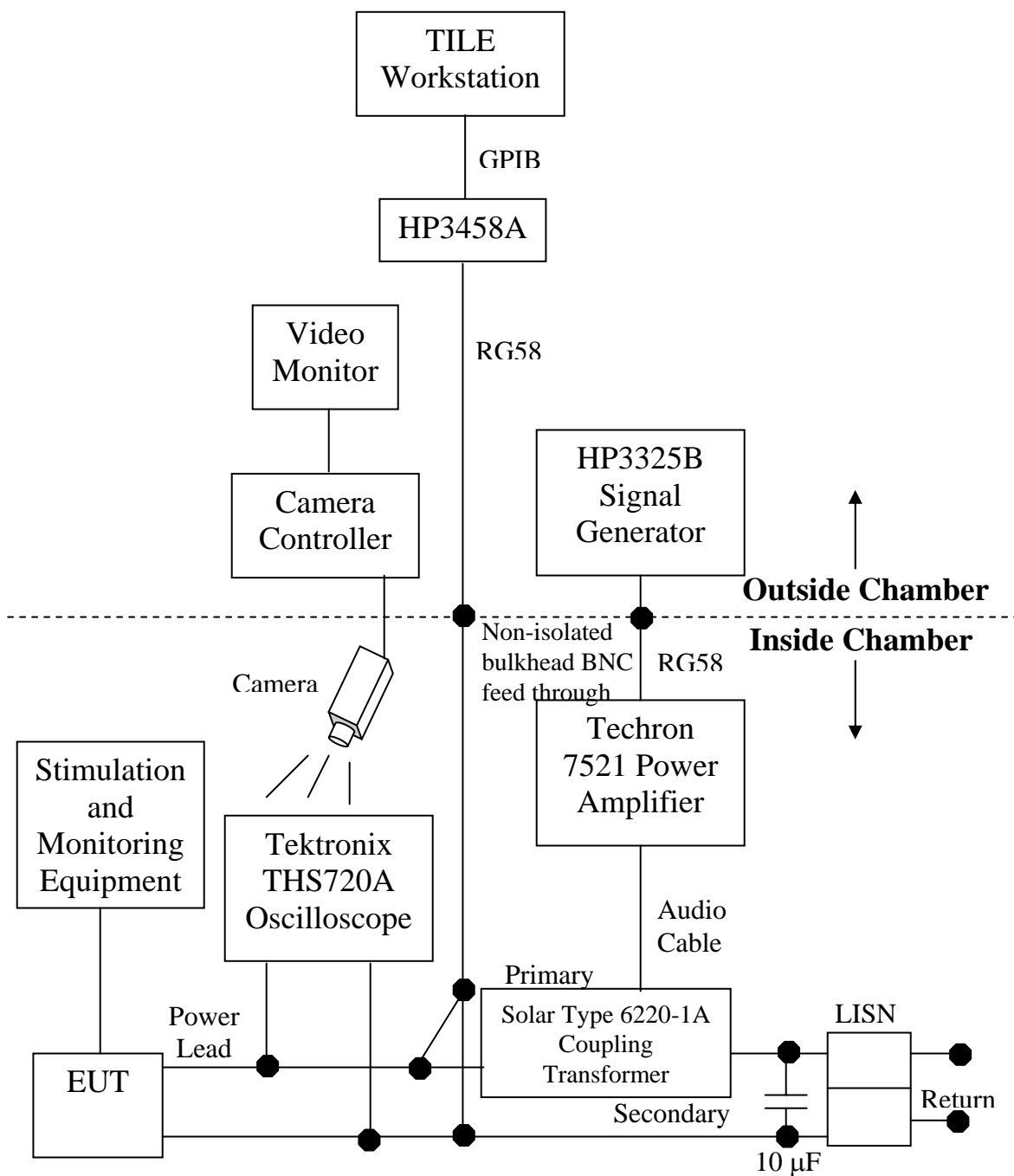


FIGURE CS101-4. Signal injection, DC or single phase AC.

| | | |
|--|-----------------|------------------------|
| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
| MIL-STD-461E EMI Testing | MFOP-FA-EMI-30X | Revision: ROUGH DRAFT4 |
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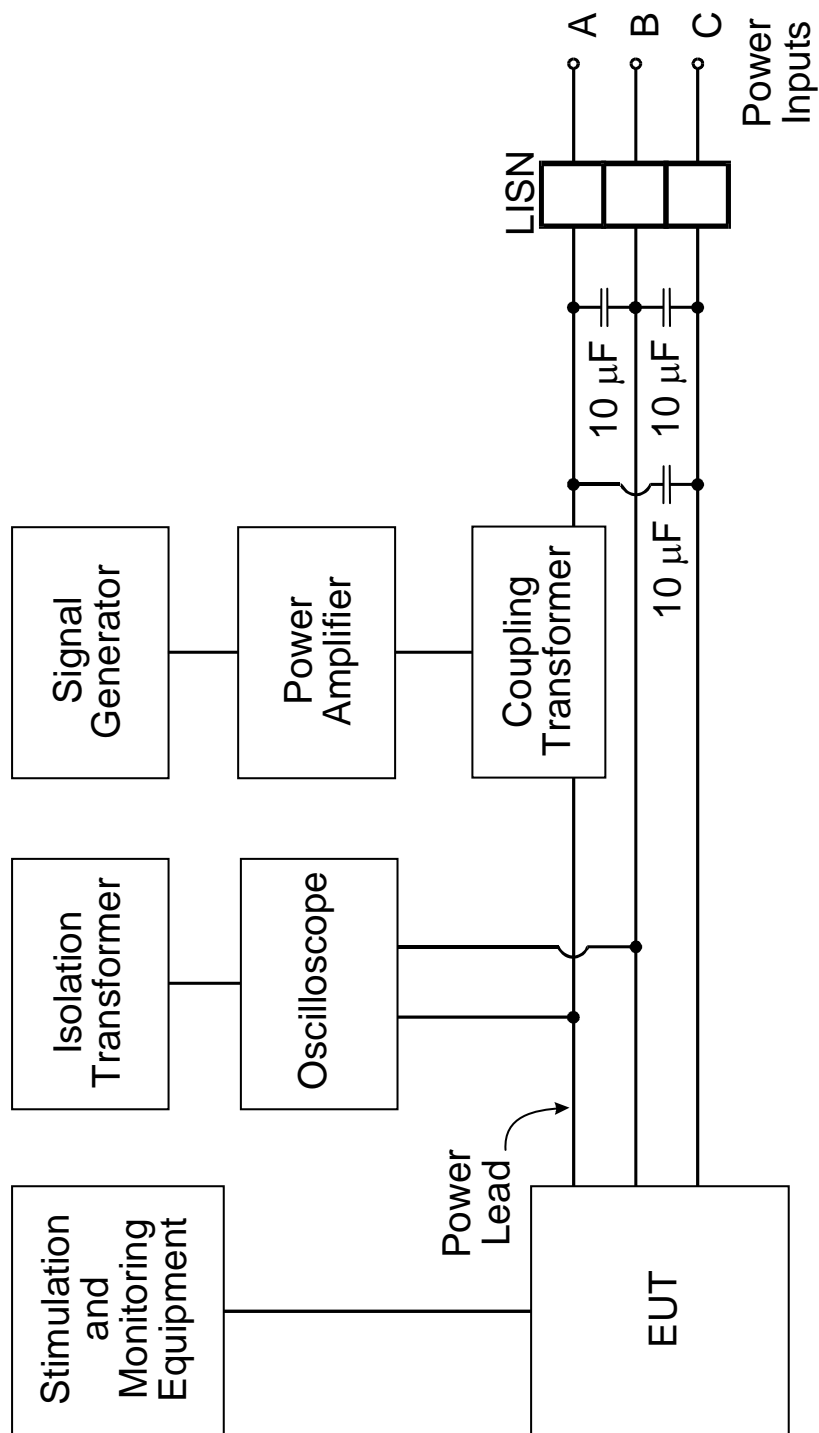


FIGURE CS101-5. Signal injection, 3-phase ungrounded.

| | | |
|--|-----------------|------------------------|
| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
| MIL-STD-461E EMI Testing | MFOP-FA-EMI-30X | Revision: ROUGH DRAFT4 |
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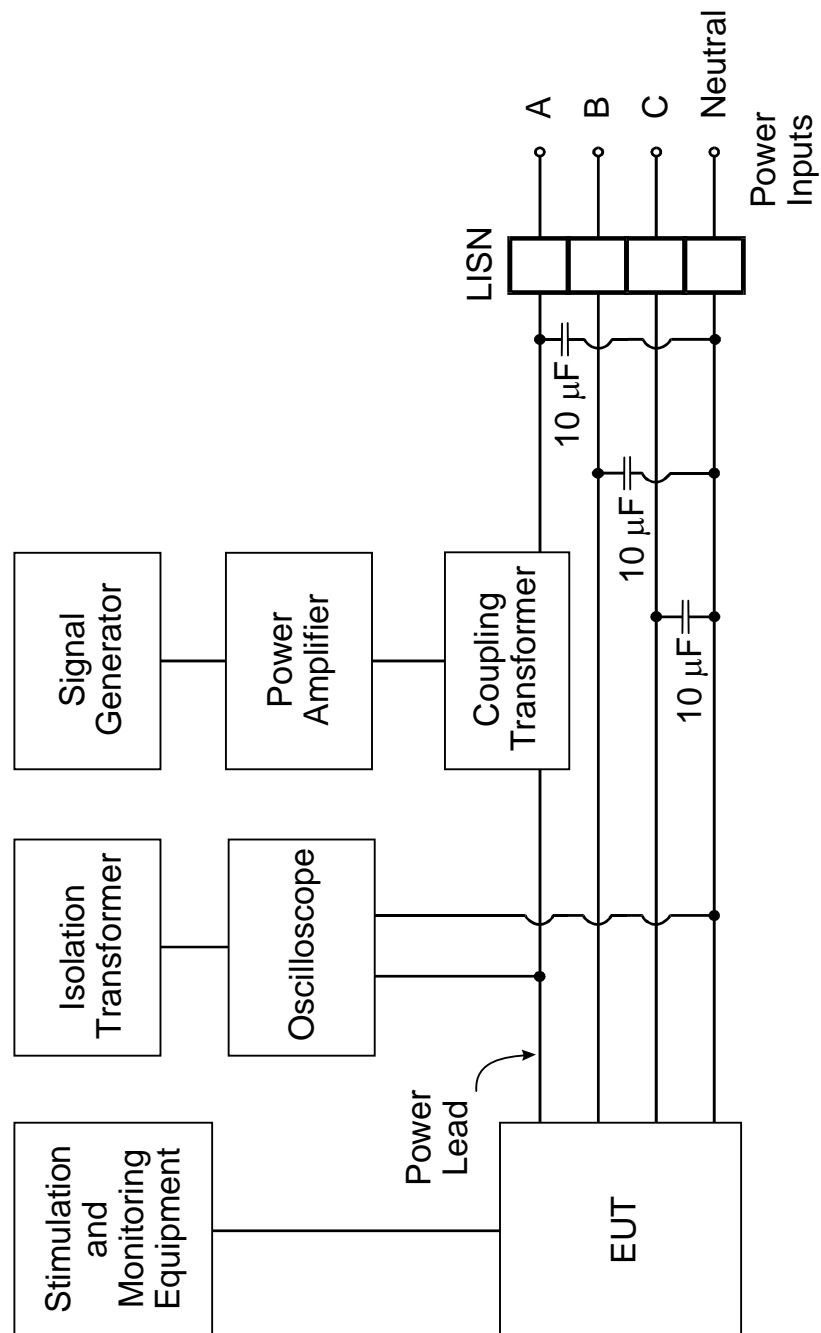


FIGURE CS101-6. Signal injection, 3-phase wye.

| | | |
|--|-----------------|------------------------|
| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
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5.12 CS114, conducted susceptibility, bulk cable injection, 10 kHz to 200 MHz.

5.12.1 CS114 applicability.

This requirement is applicable to all interconnecting cables, including power cables.

5.12.2 CS114 limit.

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to a injection probe drive level which has been pre-calibrated to the appropriate current limit shown in Figure CS114-1 and is modulated as specified below. The appropriate limit curve in Figure CS114-1 shall be selected from Table VI. Requirements are also met if the EUT is not susceptible at forward power levels sensed by the coupler that are below those determined during calibration provided that the actual current induced in the cable under test is 6 dB or greater than the calibration limit.

5.12.3 CS114 test procedures.

5.12.3.1 Purpose.

This test procedure is used to verify the ability of the EUT to withstand RF signals coupled onto EUT associated cabling.

5.12.3.2 Test equipment.

The test equipment is listed in Table CS114-1.

Table CS114-1. METF CS114 Equipment.

| Item | METF Equipment |
|--------------------------------|--|
| Measurement Receiver A | HP8590L Spectrum Analyzer, or equivalent |
| Measurement Receiver B | Boonton Model 5232 RF Power Meter/Voltmeter, or equivalent |
| Current Injector Probe | FCC Model F-120-98 10 kHz – 230 MHz |
| Current Monitor Probe < 10 MHz | Solar Type 6741-1, 100 KHz – 100 MHz, or equivalent |
| Current Monitor Probe > 10 MHz | Solar Type 9123-1N, 10kHz-500MHz, or equivalent |
| Calibration Fixture, 50Ω | EMCO Model 95241-1, 10 KHz – 450 MHz, or equivalent |
| Directional Coupler | Werlatone Model C5086, 10 KHz – 250 MHz, or equivalent |
| Signal Generator < 10 MHz | Agilent 33220A, 0.1mHz-15MHz, or equivalent |
| Signal Generator >10 MHz | Agilent E8257C, or equivalent |
| Attenuators, 50 Ω, DC to 1 GHz | Various |
| Coaxial Load, 50 Ω | Solar Type 9841-1, or equivalent |
| Power Amplifier | Ophir Model 5084, or equivalent |

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| | |
|-------------------------|---|
| LISN (Positive Lead) | Solar MIL-STD-461E LISN Model # _____ |
| LISN (Return Lead) | Solar MIL-STD-461E LISN Model # _____ |
| Test Software | Total Integrated Laboratory Environment (TILE), or equivalent |
| | |
| | |

5.12.3.3 Setup.

The test setup shall be as follows:

- a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and 4.3.8.
- b. Calibration. Configure the test equipment in accordance with Figure CS114-3 for calibrating injection probes.
 - (1) Place the injection probe around the center conductor of the calibration fixture.
 - (2) Terminate one end of the calibration fixture with a 50 ohm load and terminate the other end with an attenuator connected to measurement receiver A.
- c. EUT Testing. Configure the test equipment as shown in Figure CS114-4 for testing of the EUT.
 - (1) Place the injection and monitor probes around a cable bundle interfacing with an EUT connector.
 - (2) Locate the monitor probe 5 cm from the connector. If the overall length of the connector and backshell exceeds 5 cm, position the monitor probe as close to the connector's backshell as possible.
 - (3) Position the injection probe 5 cm from the monitor probe.

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5.12.3.4 Procedures.

The test procedures shall be as follows:

- a. Turn on the measurement equipment and allow sufficient time for stabilization.
- b. Calibration. Perform the following procedures using the calibration setup. Note that the test software performs each of these steps.
 - (1) Set the signal generator to 10 kHz, unmodulated.
 - (2) Increase the applied signal until measurement receiver A indicates the current level specified in the applicable limit is flowing in the center conductor of the calibration fixture.
 - (3) Record the "forward power" to the injection probe indicated on measurement receiver B.
 - (4) Scan the frequency band from 10 kHz to 200 MHz and record the forward power needed to maintain the required current amplitude.
- c. EUT Testing. Perform the following procedures on each cable bundle interfacing with each electrical connector on the EUT including complete power cables (high sides and returns). Also perform the procedures on power cables with the power returns and chassis grounds (green wires) excluded from the cable bundle. For connectors which include both interconnecting leads and power, perform the procedures on the entire bundle, on the power leads (including returns and grounds) grouped separately, and on the power leads grouped with the returns and grounds removed.
 - (1) Turn on the EUT and allow sufficient time for stabilization.
 - (2) Susceptibility evaluation. Steps (a) through (e) are performed by the test software.
 - (a) Set the signal generator to 10 kHz with 1 kHz pulse modulation, 50% duty cycle.
 - (b) Apply the forward power level determined under 5.12.3.4b(4) to the injection probe while monitoring the induced current.
 - (c) Scan the required frequency range in accordance with 4.3.10.4.1 and Table III while maintaining the forward power level at the calibration level determined under 5.12.3.4b(4), or the maximum current level for the applicable limit curve from Figure CS114-1 +6dB, whichever is less stringent. The amplifier gain may have to be increased at some frequencies to obtain the calibration power limit during EUT testing. The attenuator on the amplifier output may have to be removed at some frequencies to obtain the calibration power limit. These two variables do not impact the validity of the power calibration levels.
 - (d) Monitor the EUT for degradation of performance during testing.

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- (e) Whenever susceptibility is noted, determine the threshold level in accordance with 4.3.10.4.3 and verify that it is above the applicable requirement.
- (f) For EUTs with redundant cabling for safety critical reasons such as multiple data buses, use simultaneous multi-cable injection techniques.

5.12.3.5 Data presentation.

Data presentation shall be as follows:

- a. Provide amplitude versus frequency plots for the forward power levels required to obtain the calibration level as determined in 5.12.3.4b.
- b. Complete the test run log on the METF computer workstation showing scanned frequency ranges and statements of compliance with the requirements for the susceptibility evaluation of 5.12.3.4c(2) for each interface connector. Provide any susceptibility thresholds that were determined, along with their associated frequencies.

TABLE VI. CS114 limit curves.

| LIMIT CURVE # FROM FIGURE CS114-1 | | | | | | | | | | |
|-----------------------------------|----|---|----------------------|--|--------------------------------------|---|--------------------------|--------|-------|--|
| PLATFORM FREQ. RANGE | | AIRCRAFT (EXTERNAL OR SAFETY CRITICAL) | AIRCRAFT INTERNAL | ALL SHIPS (ABOVE DECKS) AND SUBMARINES (EXTERNAL)* | SHIPS (METALLIC) (BELOW DECKS) | SHIPS (NON- METALLIC) (BELOW DECKS) | SUBMARINES (INTERNAL) | GROUND | SPACE | |
| 10 kHz ↓ 2 MHz | A | 5 | 5 | 2 | 2 | 2 | 1 | 3 | 3 | |
| | N | 5 | 3 | 2 | 2 | 2 | 1 | 2 | 3 | |
| | AF | 5 | 3 | - | - | - | - | 2 | 3 | |
| 2 MHz ↓ 30 MHz | A | 5 | 5 | 5 | 2 | 4 | 1 | 4 | 3 | |
| | N | 5 | 5 | 5 | 2 | 4 | 1 | 2 | 3 | |
| | AF | 5 | 3 | - | - | - | - | 2 | 3 | |
| 30 MHz ↓ 200 MHz | A | 5 | 5 | 5 | 2 | 2 | 2 | 4 | 3 | |
| | N | 5 | 5 | 5 | 2 | 2 | 2 | 2 | 3 | |
| | AF | 5 | 3 | - | - | - | - | 2 | 3 | |

KEY: A = Army
N = Navy
AF = Air Force

* For equipment located external to the pressure hull of a submarine but within the superstructure, use SHIPS (METALLIC)(BELOW DECKS)

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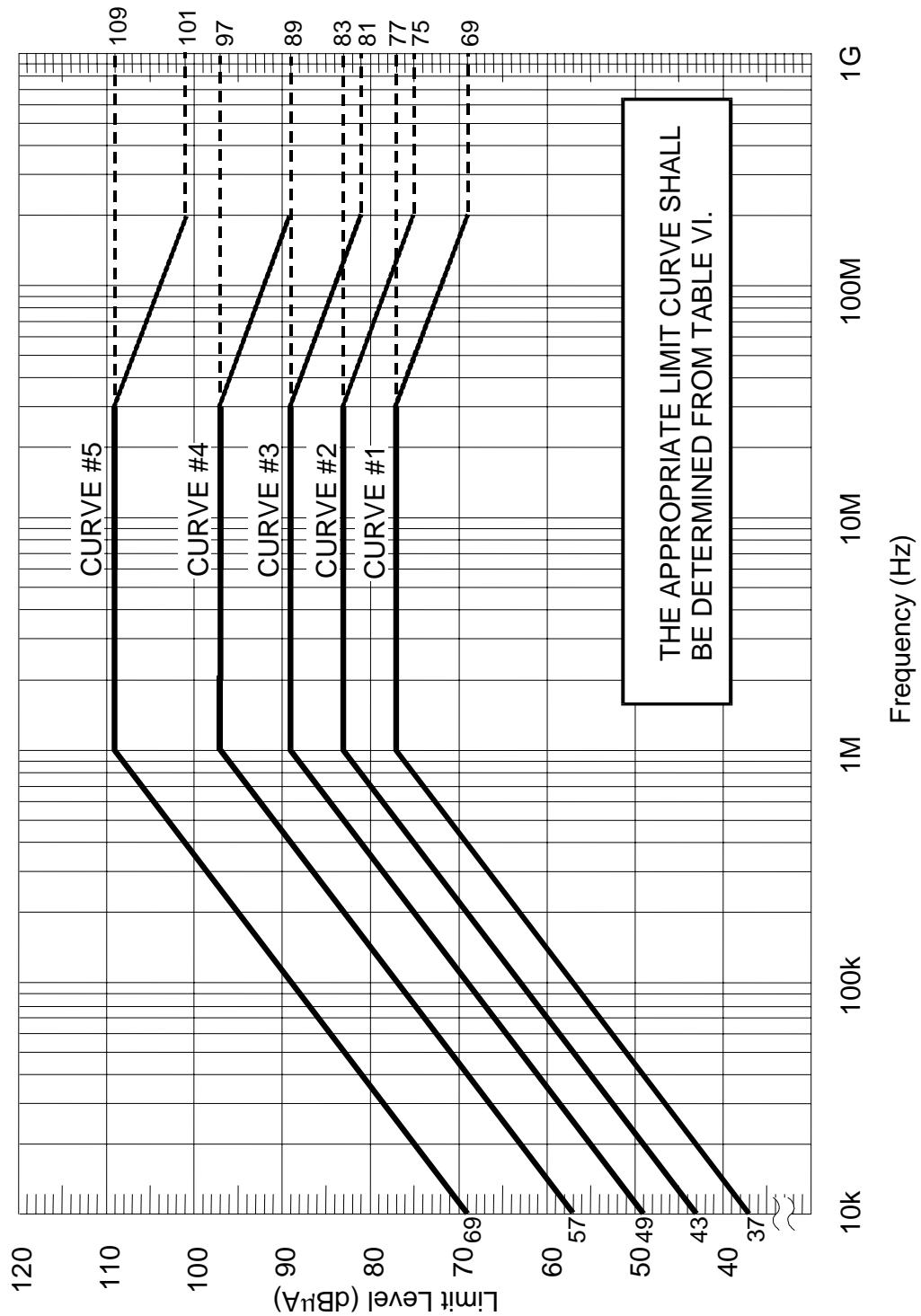


FIGURE CS114-1. CS114 calibration limit for all applications.

CS114

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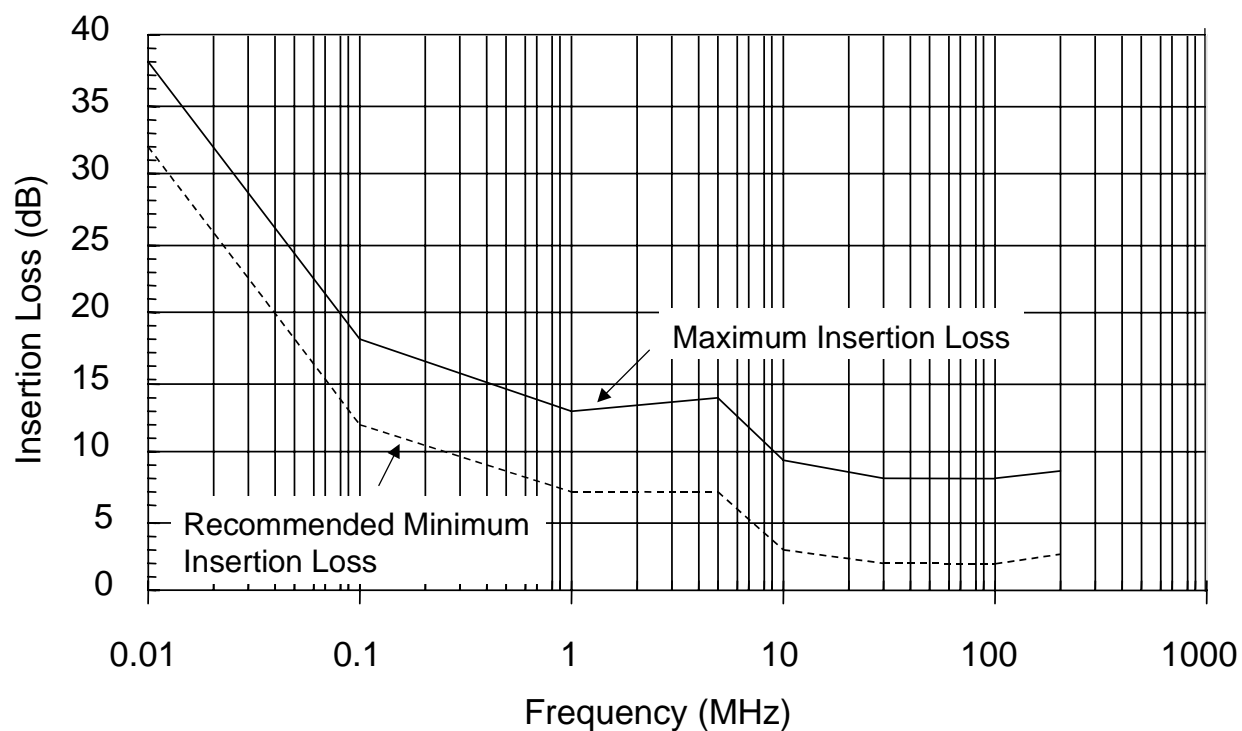


FIGURE CS114-2. Maximum insertion loss for injection probes.

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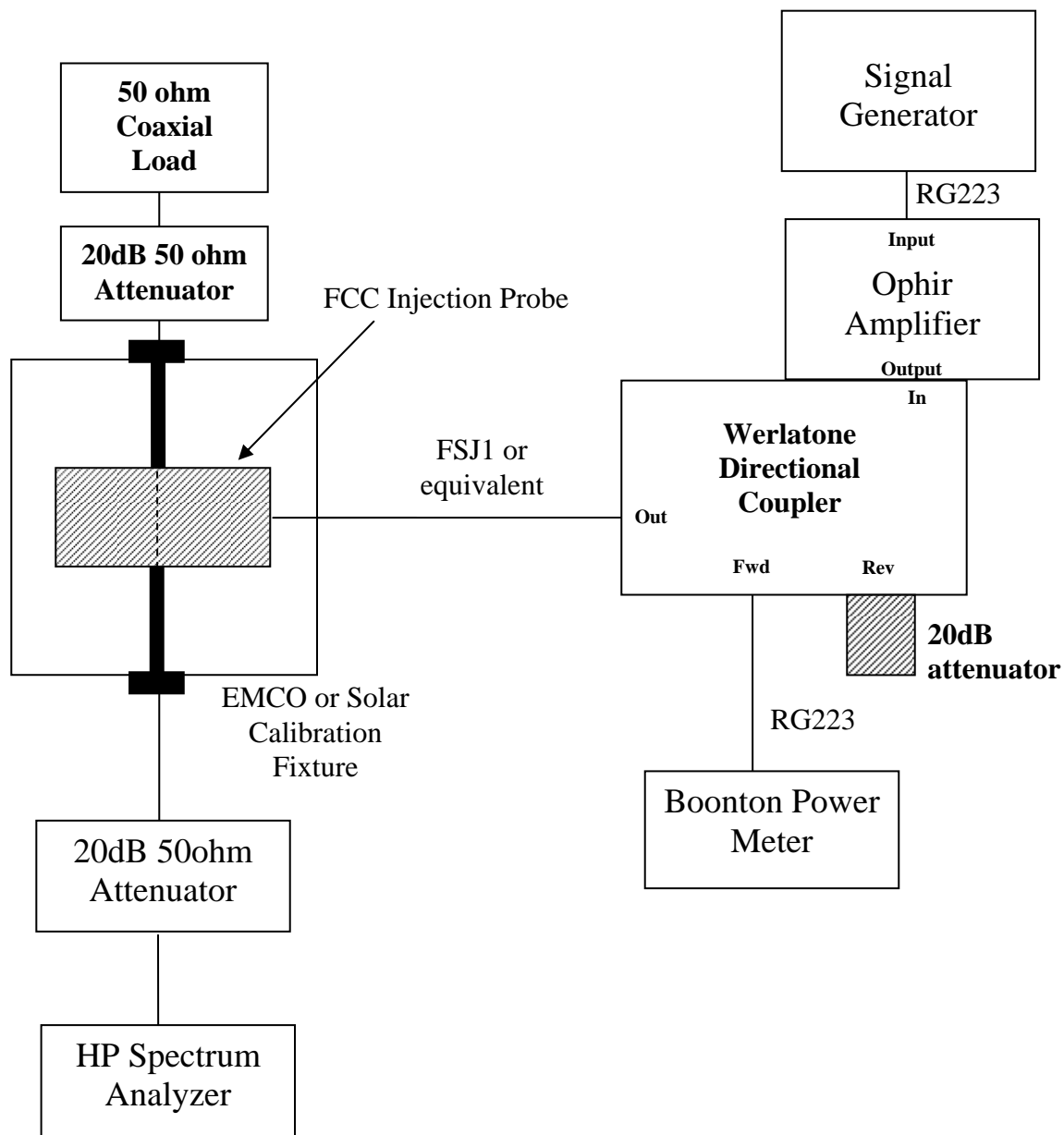


FIGURE CS114-3. Calibration setup.

| | | |
|--|-----------------|------------------------|
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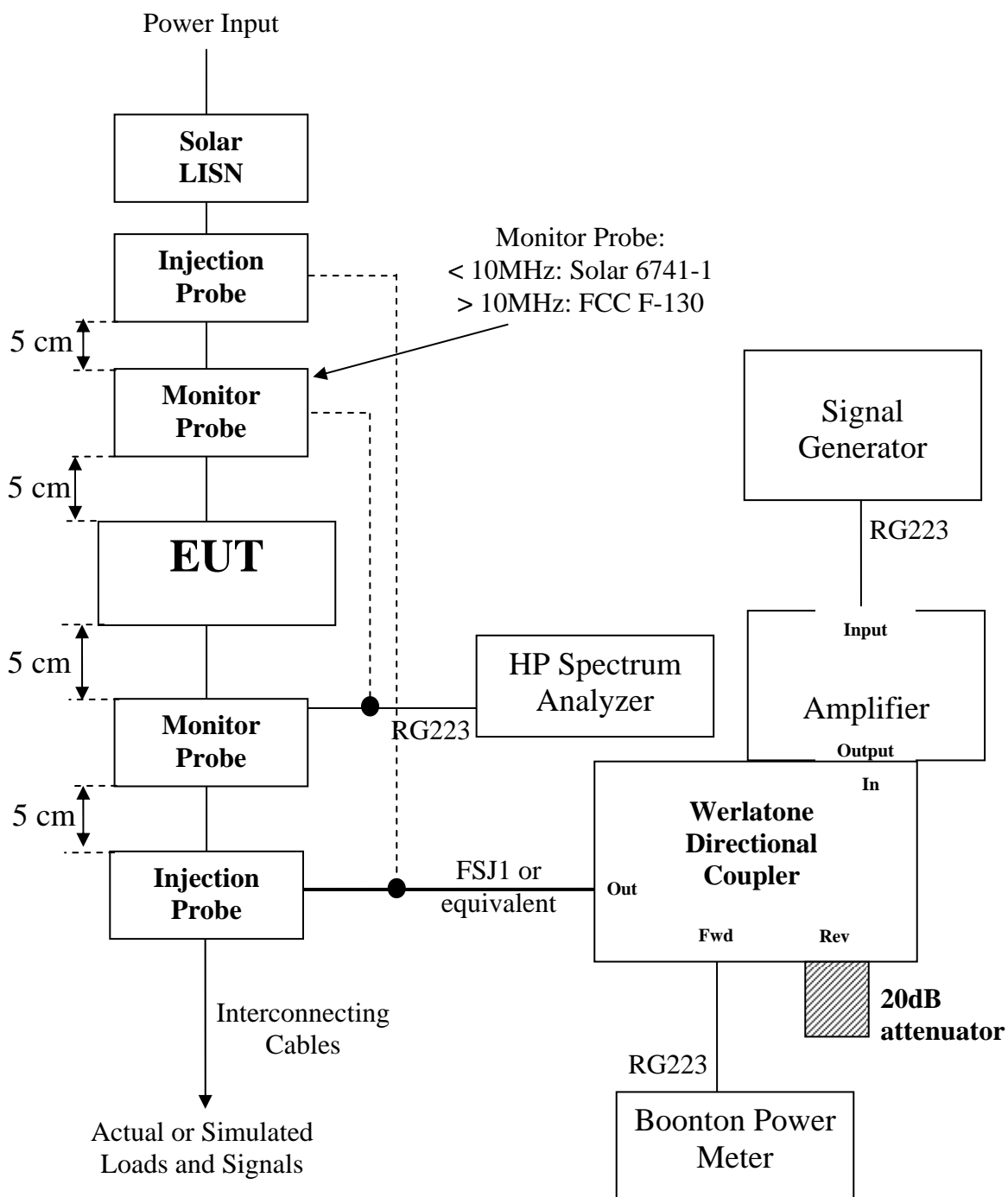


FIGURE CS114-4. Bulk cable injection evaluation.

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5.13 CS115, Conducted susceptibility, bulk cable injection, impulse excitation.

5.13.1 CS115 applicability.

This requirement is applicable to all aircraft, space, and ground system interconnecting cables, including power cables. The requirement is also applicable for surface ship and submarine subsystems and equipment when specified by the procuring activity..

5.13.2 CS115 limit.

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystems specification, when subjected to a pre-calibrated signal having rise and fall times, pulse width, and amplitude as specified in Figure CS115-1 at a 30 Hz rate for one minute.

5.13.3 CS115 test procedures.

5.13.3.1 Purpose.

This test procedure is used to verify the ability of the EUT to withstand impulse signals coupled onto EUT associated cabling.

5.13.3.2 Test equipment.

The test equipment shall be as follows:

Table CS115-1. METF CS115 Equipment.

| Item | METF Equipment | Serial # | Calibration ID | Calibration Due Date |
|--|--|----------|----------------|----------------------|
| Pulse generator, 50 ohm, charged line (coaxial) | Solar Model 9355-1 pulse generator | | N/A | N/A |
| Current injection probe | Solar Type 9142-1N, 200MHz-500MHz, or equivalent | | N/A | N/A |
| Drive cable, 50 ohm, 2 meters, 0.5 dB insertion loss at 500MHz | Andrews FSJ1 heliax cable, 50 ohm, 2 meters, or equivalent | | N/A | N/A |
| Current probe | Solar Type 9123-1N, 10kHz-500MHz, or equivalent | | | |
| | | | | |

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| Item | METF Equipment | Serial # | Calibration ID | Calibration Due Date |
|---|--|----------|----------------|----------------------|
| Calibration fixture: coaxial transmission line with 50 ohm characteristic impedance, coaxial connections on both ends, and space for an injection probe around the center conductor | Solar Model 9125-1N calibration fixture, 20Hz-500MHz, or equivalent | | N/A | N/A |
| Oscilloscope, 50 ohm input impedance | Tektronix TDS640A oscilloscope, 500MHz, or equivalent | | | |
| Attenuators, 50 ohm | Solar Model 9410-1 40dB attenuators, 2 each | N/A | N/A | N/A |
| Coaxial loads, 50 ohm | Solar Model 9841-1 | N/A | N/A | N/A |
| Calibration fixture for calibrating Solar Type 9123-1N current probe | Solar Model 925-1, 20Hz-500MHz | | N/A | N/A |
| Monitor cable | Andrews FSJ1 heliax cable, 50 ohm, 2 meters, and connectors for monitor probe and oscilloscope | | N/A | N/A |
| LISN (Positive Lead) | Solar MIL-STD-461E LISN Model # _____ | | | |
| LISN (Return Lead) | Solar MIL-STD-461E LISN Model # _____ | | | |
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5.13.3.3 Setup.

The test setup shall be as follows:

- a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and 4.3.8.
- b. Calibration. Configure the test equipment in accordance with Figure CS115-2 for calibrating the injection probe.
 - (1) Place the Solar 9142-1N injection probe around the center conductor of the Solar 9125-1N calibration fixture.
 - (2) Connect the Solar 9142-1N injection probe to the output N connector on the Solar 9355-1 pulse generator using the Andrews FSJ1 drive cable.
 - (3) Terminate one end of the calibration fixture with a Solar 9841-1 coaxial load and terminate the other end with a Solar 9410-1 (input side of attenuator) attenuator.
 - (4) Connect output side of Solar 9410-1 attenuator to Tektronix TDS640A input.
 - (5) Set TDS640A input impedance to 50 ohms.
- c. EUT Testing. Configure the test equipment as shown in Figure CS115-3 for testing of the EUT.
- d. Record any deviations from the CS115 calibration and EUT testing setups on CS115 deviation sheet(s) as needed.
 - (1) Place the injection and monitor probes around a cable bundle interfacing with an EUT connector.
 - (2) Locate the monitor probe 5 cm from the connector. If the overall length of the connector and backshell exceeds 5 cm, position the monitor probe as close to the connector's backshell as possible.
 - (3) Position the injection probe 5 cm from the monitor probe.

5.13.3.4 Procedures.

The test procedures shall be as follows:

- a. Turn on the measurement equipment and allow sufficient time for stabilization.
- b. Calibration. Perform the following procedures using the calibration setup.
 - (1) Adjust the pulse generator source for the rise time, pulse width, and pulse repetition rate requirements specified in the requirement.
 - (a) Set pulse repetition rate to 30 on the 9355-1 display using the band 3 pps range button and the pps adjustment knob.
 - (b) Set pulse polarity to + on the 9355-1.

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(2) Increase the signal applied to the calibration fixture until the oscilloscope indicates that the current level specified in the requirement is flowing in the center conductor of the calibration fixture. Use oscilloscope settings 1.00 V Ω /division and 5 ns/division for initial settings.

(a) The voltage across the 50 ohm load which gives 5A is 250V (250V/50 Ω = 5A). Adjust the 9355-1 amplitude to achieve 2.5V peak amplitude on the rising edge of the SC115 pulse. 2.5 V is the displayed scope voltage due to the 9410-1 40 dB attenuator (factor of 100 reduction).

(3) Verify that the rise time, fall time, and pulse width portions of the waveform have the correct durations and that the correct repetition rate is present. The precise pulse shape will not be reproduced due to the inductive coupling mechanism.

(a) Amplitude = 2.5V peak _____
Pulse width = _____ (30 nsec minimum) _____
Rise time \leq 2 nsec _____
Fall time \leq 2 nsec _____
Repetition rate = _____ (30 Hz) _____

(b) Print plots from the oscilloscope showing:

Amplitude and pulse width _____
Rise time _____
Fall time _____
Pulse repetition rate _____

(4) Record the pulse generator amplitude setting that achieves the 5A current level in the 50 Ω load.

- c. Broadband correction factor calibration for Solar Type 9123-1N monitor probe.
The Solar 9123-1N current monitor probe is provided with a standard correction factor (dBCF) graph that presents dBCF verses frequency over the probe frequency range of 10 KHz – 500 MHz. This graph is only useful for narrow band signals that are confined to a known frequency or a narrow frequency range. This graph is useless for any broadband impulse signal spread out over the entire probe frequency range. A single broadband correction factor can be determined for the monitoring probe and used to accurately measure a broadband impulse signal, independent of the circuit under test. This factor only has to be determined once for a CS115 test as long as the individual equipment test items used in the calibration setup and the EUT remain the same (overall rise and fall times of the generated CS115 waveform remain the same).

CS115

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- (1) Using the calibration setup in Figure CS115-2, find the 9355-1 amplitude settings which gives a peak voltage reading of 400V (4 V on oscilloscope). This provides a peak current of $400 \text{ V} / 50 \Omega = 8 \text{ amperes}$. When complete, reduce the 9355-1 amplitude to 0.
- (2) Modify the calibration setup to match figure CS115-3. This consists of modifying the Figure CAS115-2 cal setup as follows:
 - (a) Move Solar 9841-1 50Ω load from Solar 9125-1N calibration fixture to the Solar 9251-1 small calibration fixture.
 - (b) Connect the Solar 9351-1 small calibration fixture in series with the Solar 9125-1 calibration fixture.
 - (c) Clamp the Solar 9123-1N current monitor probe around the Solar 9251-1 calibration fixture center conductor.
 - (d) Connect a Solar 9410-1 40dB attenuator to the output of the solar 9123-1N current probe.
- (3) Set the 9355-1 amplitude to the same setting as in step (1). Measure the peak voltage output on the oscilloscope. The addition of the additional calibration fixture and current probe will slightly decrease the voltage observed in step (1). Multiply the scope reading by 100 (40 dB attenuator). Now calculate the current flowing in the center conductor as: $\text{___ V} / 50 \Omega = \text{___ amperes}$.
- (4) Remove the oscilloscope cable from the Solar 9410-1 attenuator in the large calibration fixture and connect it to the 9410-1 attenuator on the Solar 9123-1N current probe. The oscilloscope voltage will be greatly reduced from that seen in steps (1) and (3).
- (5) Record the oscilloscope voltage from step (4).
- (6) The 9123-1N broadband probe impedance factor required to provide the current in step (3) is the same current measured by the first 9410-1 attenuator still in the voltage from step (5)/current from step (3) = $\text{___} \Omega = Z_B$
- (7) This impedance factor is then used to calculate the current induced in the EUT cables using the following equation:

$$(\text{peak scope voltage} * 100) / Z_B = \text{peak injected current on EUT cable, amperes}$$

d. EUT Testing.

- (1) Turn on the EUT and allow sufficient time for stabilization.
- (2) Susceptibility evaluation.

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- (a) Slowly increase the pulse generator amplitude to the amplitude setting determined in 5.13.3.4b(4). This is the maximum value to be injected.
- (b) Apply the test signal at the pulse repetition rate and for the duration specified in the requirement.
- (c) Monitor the EUT for degradation of performance during testing.
- (d) Whenever susceptibility is noted, determine the threshold level in accordance with 4.3.10.4.3 and verify that it is above the limit.
- (e) Record the peak current induced in the cable as indicated on the oscilloscope using the Z_B factor from step____.
- (f) Repeat 5.13.3.4c(2)(a) through 5.13.3.4c(2)(e) on each cable bundle interfacing with each electrical connector on the EUT. For power cables, perform 5.13.3.4c(2)(a) through 5.13.3.4c(2)(e) on complete power cables (high sides and returns) and on the power cables with the power returns and chassis grounds (green wires) excluded from the cable bundle. For connectors which include both interconnecting leads and power, perform 5.13.3.4c(2)(a) through 5.13.3.4c(2)(e) on the entire bundle, on the power leads (including returns and grounds) grouped separately, and on the power leads grouped with the returns and grounds removed.
- (g) Record any deviations from the standard CS115 calibration and EUT test procedures on CS115 deviation sheets as needed.

5.13.3.5. Data presentation.

Data presentation shall be as follows:

- a. Provide tables showing statements of compliance with the requirement for the susceptibility evaluation of 5.13.3.4c(2) and the induced current level for each interface connector.
- b. Provide any susceptibility thresholds that were determined.
- c. Provide oscilloscope photographs of injected waveforms with test data.

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EUT: _____

| Cable Under Test | Pass/Effect | Observed Effect(s) | Threshold Level |
|------------------|-------------|--------------------|-----------------|
| | | | |
| | | | |
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Table CS115-1. CS115 Test Results

| | | |
|--|-----------------|------------------------|
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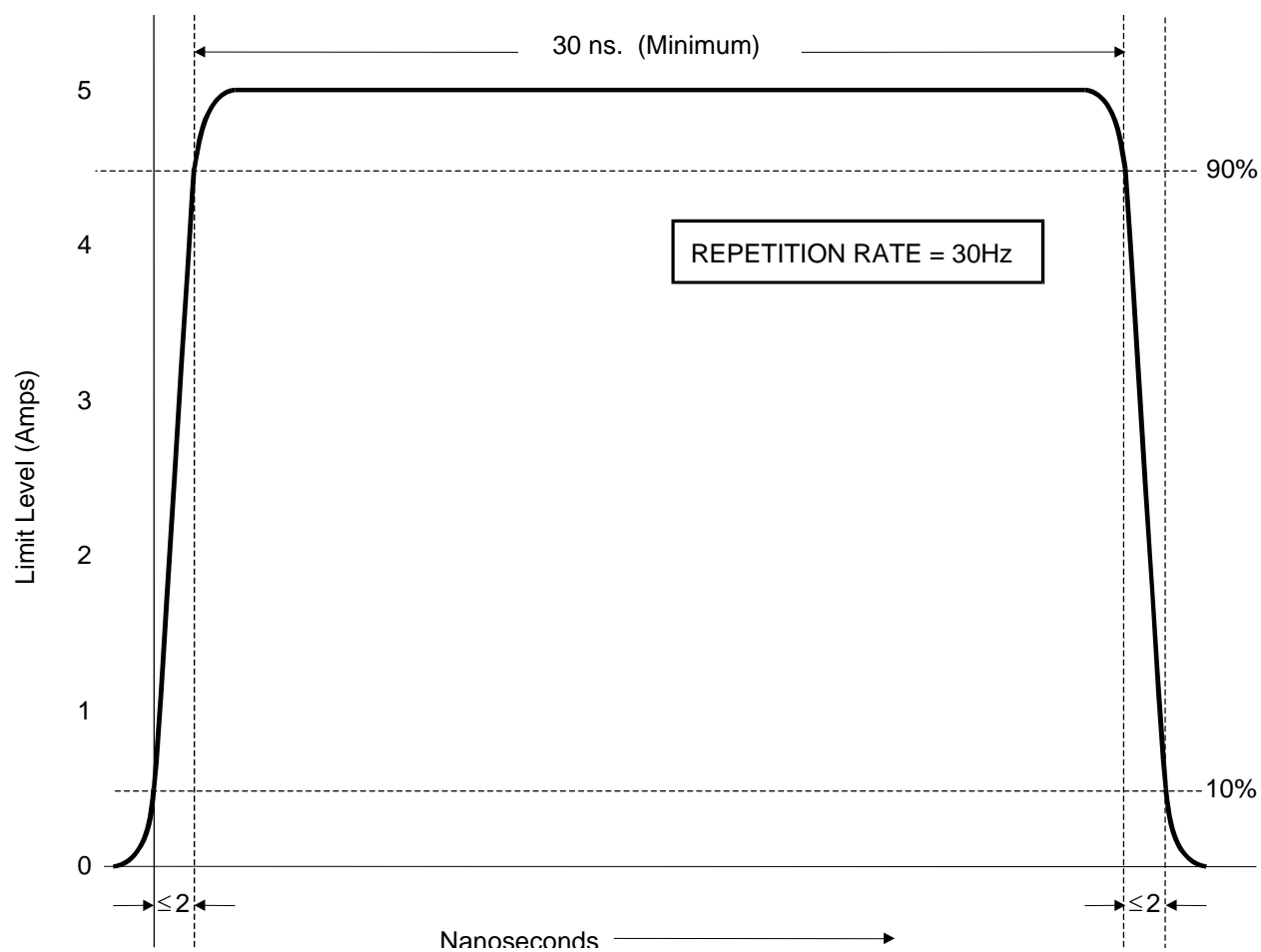


FIGURE CS115-1. CS115 signal characteristics for all applications.

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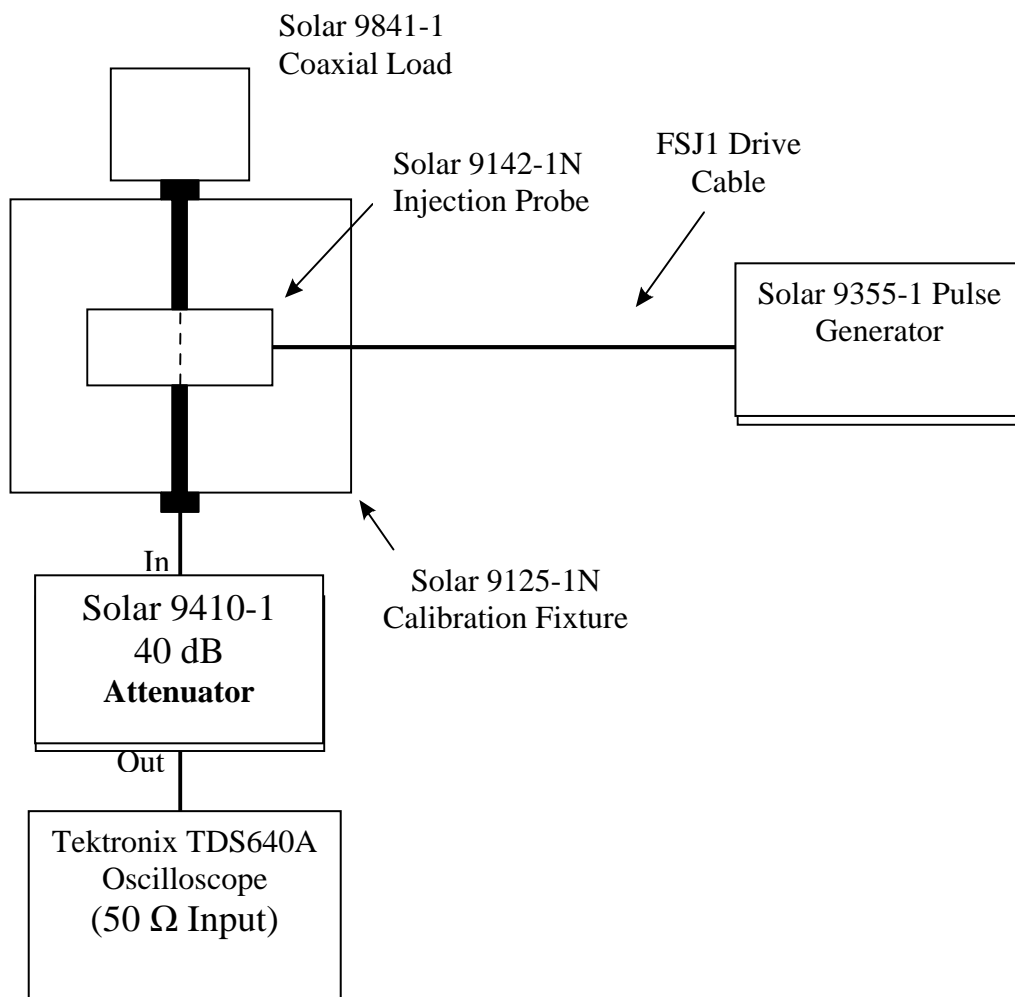


FIGURE CS115-2. Calibration setup.

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|--|-----------------|------------------------|
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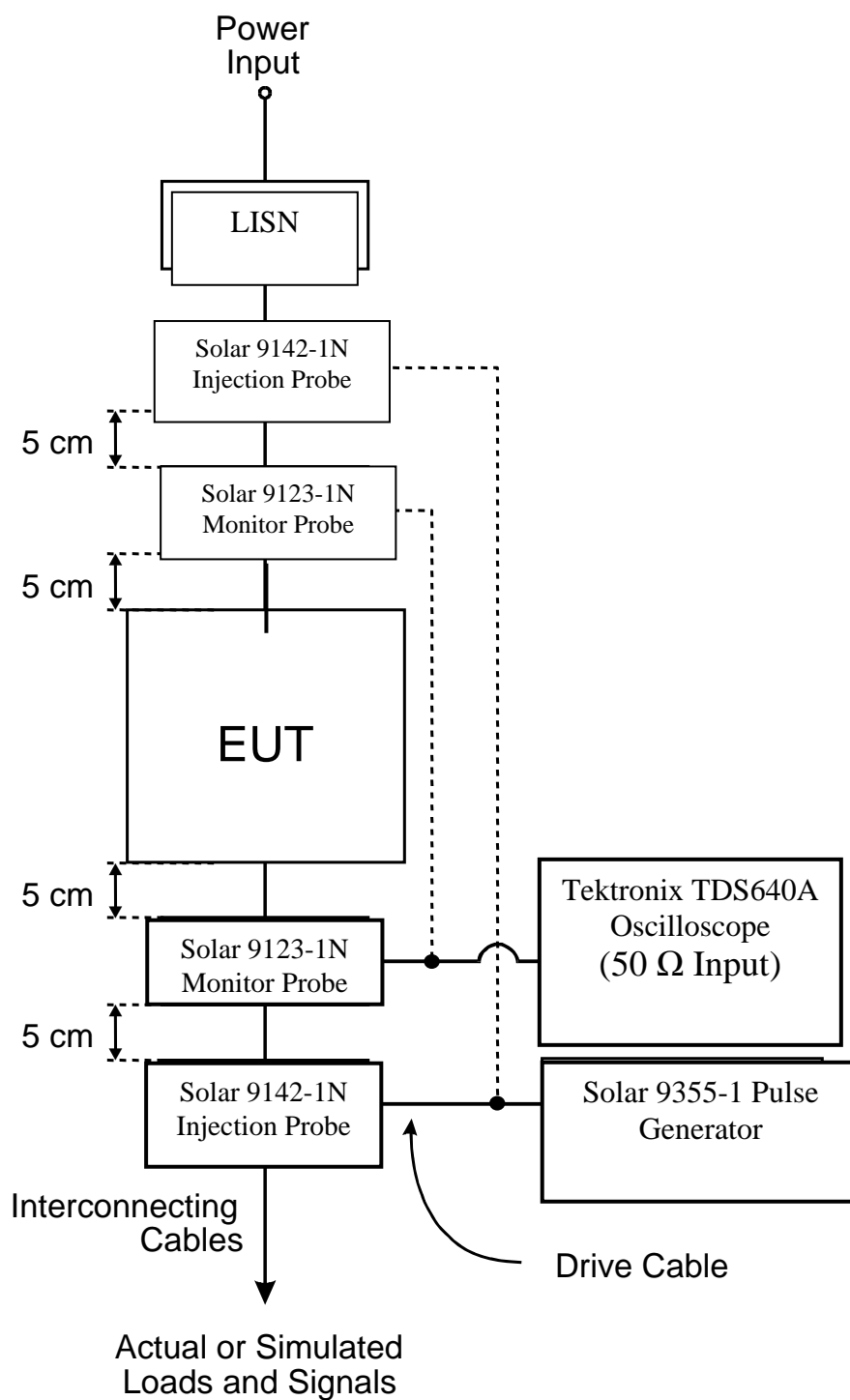


Figure CS115-4. Bulk Cable injection.

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|--|-----------------|------------------------|
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5.14 CS116, conducted susceptibility, damped sinusoidal transients, cables and power leads, 10 kHz to 100 MHz.

5.14.1 CS116 applicability.

This requirement is applicable to all interconnecting cables, including power cables, and individual high side power leads. Power returns and neutrals need not be tested individually.

5.14.2 CS116 limit.

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to a signal having the waveform shown in Figure CS116-1 and having a maximum current as specified in Figure CS116-2. The limit is applicable across the entire specified frequency range. As a minimum, compliance shall be demonstrated at the following frequencies: 0.01, 0.1, 1, 10, 30, and 100 MHz. If there are other frequencies known to be critical to the equipment installation, such as platform resonance, compliance shall also be demonstrated at those frequencies. The test signal repetition rate shall be no greater than one pulse per second and no less than one pulse every two seconds. The pulses shall be applied for a period of five minutes.

5.14.3 CS116 test procedures.

5.14.3.1 Purpose.

This test procedure is used to verify the ability of the EUT to withstand damped sinusoidal transients coupled onto EUT associated cables and power leads..

5.14.3.2 Test equipment.

The test equipment shall be as follows:

Table CS116-1. METF CS116 Equipment.

| Item | METF Equipment | NEMS# | Calibration ID | Calibration Due Date |
|--|--|-------|----------------|----------------------|
| Damped sinusoid transient generator, < 100ohm output impedance | Solar Model 9351-1 | | | |
| Current injection probe | Solar Type 9335-2 current injection probe, 10kHz-10MHz | | | |
| Current injection probe | Solar 9142-1N current injection probe, 2MHz-500MHz | | | |
| Oscilloscope, 50 ohm input | Tektronix TDS640A | | | |

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| | | | | |
|--|---|-----|-----|-----|
| impedance | oscilloscope, 500MHz | | | |
| Calibration fixture: coaxial transmission line with 50 ohm characteristic impedance, coaxial connections on both ends, and space for an injection probe around the center conductor | Solar Type 9357-1 calibration fixture, 20Hz- 100MHz | | | |
| Calibration fixture: coaxial transmission line with 50 ohm characteristic impedance, coaxial connections on both ends, and space for an injection probe around the center conductor | Solar Type 9125-1 calibration fixture, 20Hz- 500MHz | | | |
| Current probe | Solar Type 9123-1N current probe, 10kHz- 500MHz | | | |
| Current probe | Solar Type 6741-1 current probe, 10kHz-100MHz | | | |
| Waveform recording device | HP business inkjet 2280 | N/A | N/A | N/A |
| Attenuators, 50 ohm | Solar Model 9410-1 40dB attenuators, 2 each | | N/A | N/A |
| Coaxial loads, 50 ohm | Solar Model 9841-1 | | | |
| Injection cable | Andrews FSJ4 6 foot 50 ohm injection cable | | | |
| Injection cable (100MHz) | Andrews 12 foot FSJ4 50 ohm injection cable | | | |
| Injection cable (30 MHz) | 6 foot 93 ohm injection cable | | | |
| Measurement cable | Andrews 6 foot FSJ4 50 ohm measurement cable | | | |

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| | | | | |
|-------------------------|---|--|--|--|
| LISN (Positive Lead) | Solar MIL-STD-461E LISN Model # _____ | | | |
| LISN (Return Lead) | Solar MIL-STD-461E LISN Model # _____ | | | |
| | | | | |

5.14.3.3. Setup.

The test setup shall be as follows:

- a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and 4.3.8.
- b. Calibration. Configure the test equipment in accordance with Figure CS116-3 and CS116-4 for verification of the waveform.
- c. EUT Testing:
 - (1) Configure the test equipment as shown in Figures CS116-5 and CS116-6.
 - (2) Place the injection and monitor probes around a cable bundle interfacing with an EUT connector.
 - (3) Locate the monitor probe 5 cm from the connector. If the overall length of the connector and backshell exceeds 5 cm, position the monitor probe as close to the connector's backshell as possible.
 - (4) Position the injection probe 5 cm from the monitor probe.

5.14.3.4 Procedures.

The test procedures shall be as follows:

- a. Turn on the measurement equipment and allow sufficient time for stabilization.
- b. Calibration. Perform the following procedures using the calibration setup for waveform verification.
 - (1) Set the frequency of the damped sine generator at 10 kHz.
 - (2) Adjust the amplitude of the signal from the damped sine generator to the level specified in the requirement.
 - (3) Record the damped sine generator settings in Table CS116-1.
 - (4) Note: For the 10 KHz waveform, the 9354-1 discharge reference voltage will be very low. When the correct voltage is reached on the oscilloscope, mark the 9354-1 amplitude dial setting with tape on the 9354-1 face. The marked amplitude is the maximum allowed amplitude setting for the EUT testing.

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- (5) Verify that the waveform complies with the requirements. Calculate Q and enter in Table CS116-1.
- (5) Repeat 5.14.3.4b(2) through 5.14.3.4b(4) for each frequency specified in the requirement and those identified in 5.14.3.4c(2). Ensure that 9354-1 is set to the correct waveform for each run.
- c. EUT testing. Perform the following procedures, using the EUT test setup on each cable bundle interfacing with each connector on the EUT including complete power cables. Also perform tests on each individual high side power lead (individual power returns and neutrals are not required to be tested).
 - (1) Turn on the EUT and measurement equipment to allow sufficient time for stabilization.
 - (2) From Solar 9123-1N calibration sheet, calculate probe transfer impedance by:
 - (a) At 10 KHz, read probe correction factor (CF) in dB from the cal sheet.
 - (b) $Z_T = 10^{\frac{-CF}{20}}$
 - (c) Obtain Z_T at 10 KHz, 100 KHz, 1 MHz, 10 MHz, 30 MHz, and 100 MHz and enter in Table CS116-2.
 - (3) Set the damped sine generator to a test frequency.
 - (4) Apply the test signals to each cable or power lead of the EUT sequentially. Slowly increase the damped sine wave generator output level to provide the specified current, but not exceeding the precalibrated generator output level. Record the peak current obtained. Peak current = peak scope voltage / Z_T at waveform frequency.
 - (4) Monitor the EUT for degradation of performance.
 - (5) If susceptibility is noted, determine the threshold level in accordance with 4.3.10.4.3 and verify that it is above the specified requirements.
 - (6) Repeat 5.14.3.4c(2) through 5.14.3.4c(5) for each test frequency as specified in the requirement. Repeat testing in 5.14.3.4c for the power-off condition.

| | | |
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5.14.3.5. Data presentation.

Data presentation shall be as follows:

- a. Provide a list of the frequencies and amplitudes at which the test was conducted for each cable and lead in Table CS116-2.
- b. Provide data on any susceptibility thresholds and the associated frequencies that were determined for each connector and power lead in Table CS116-2.
- c. Provide indications of compliance with the requirements for the susceptibility evaluation specified in 5.14.3.4c for each interface connector Table CS116-2.
- d. Provide oscilloscope photographs of injected waveforms with test data.
- e. Provide current monitor probe calibration sheets.

| | | |
|--|-----------------|------------------------|
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EUT:_____

Date:_____

$I_{MAX} = 10$ Amperes

| Run/Print | Frequency (Hz) | I_P (A) | V_P into 50 Ω load (V) ¹ | V_{PS} on scope with 40 dB attenuator (V) ² | Calculated Q | 9354-1 setting | Scope Settings | |
|-----------|-------------------|--------------|--|---|-----------------|----------------|----------------|--------------|
| | | | | | | | V/div | Sec/div |
| | 10 K | 0.1 | 5 | 0.050 | | | 20 mV | 50 μ sec |
| | 100 K | 1 | 50 | 0.5 | | | 200mV | 5 μ sec |
| | 1 M | 10 | 500 | 5 | | | 2 V | 500 nsec |
| | 10 M | 10 | 500 | 5 | | | 2 V | 50 nsec |
| | 30 M | 10 | 500 | 5 | | | 2 V | 25 nsec |
| | 100 M | 3 | 150 | 1.5 | | | 500 mV | 25 nsec |

Notes:

1. $V_P = I_P * 50$
2. $V_{PS} = V_P / 100$

Table CS116-1. CS116 Calibration Data.

| | | |
|--|-----------------|------------------------|
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EUT: _____

Cable Under Test: _____

Date: _____

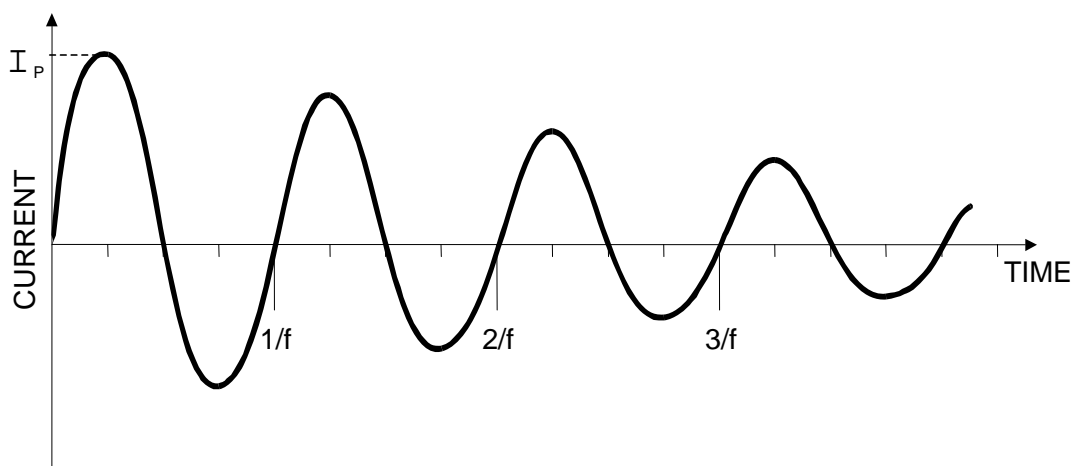
| Run / Plot Numbers | CS116 Waveform Frequency (Hz) | CS116 I _P (A) | V _P (V) | Probe Z _T (Ω) | I _P ¹ (A) | EUT Effect | 9354-1 discharge reference voltage | 9354-1 power limited (Y/N) | Pass / Effect |
|--------------------|-------------------------------|--------------------------|--------------------|--------------------------|---------------------------------|------------|------------------------------------|----------------------------|---------------|
| | 10 K | 0.1 | | | | | | | |
| | 100 K | 1 | | | | | | | |
| | 1 M | 10 | | | | | | | |
| | 10 M | 10 | | | | | | | |
| | 30 M | 10 | | | | | | | |
| | 100 M | 3 | | | | | | | |

Notes:

1. $I_P = V_P / Z_T$

Table CS116-2. CS116 Test Results.

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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NOTES: 1. Normalized waveform: $e^{-(\pi f t)/Q} \sin(2\pi f t)$

Where:

f = Frequency (Hz)

t = Time (sec)

Q = Damping factor, 15 ± 5

2. Damping factor (Q) shall be determined as follows:

$$Q = \frac{\pi(N - 1)}{\ln(I_P/I_N)}$$

Where:

Q = Damping factor

N = Cycle number (i.e. $N = 2, 3, 4, 5, \dots$)

I_P = Peak current at 1st cycle

I_N = Peak current at cycle closest to 50% decay

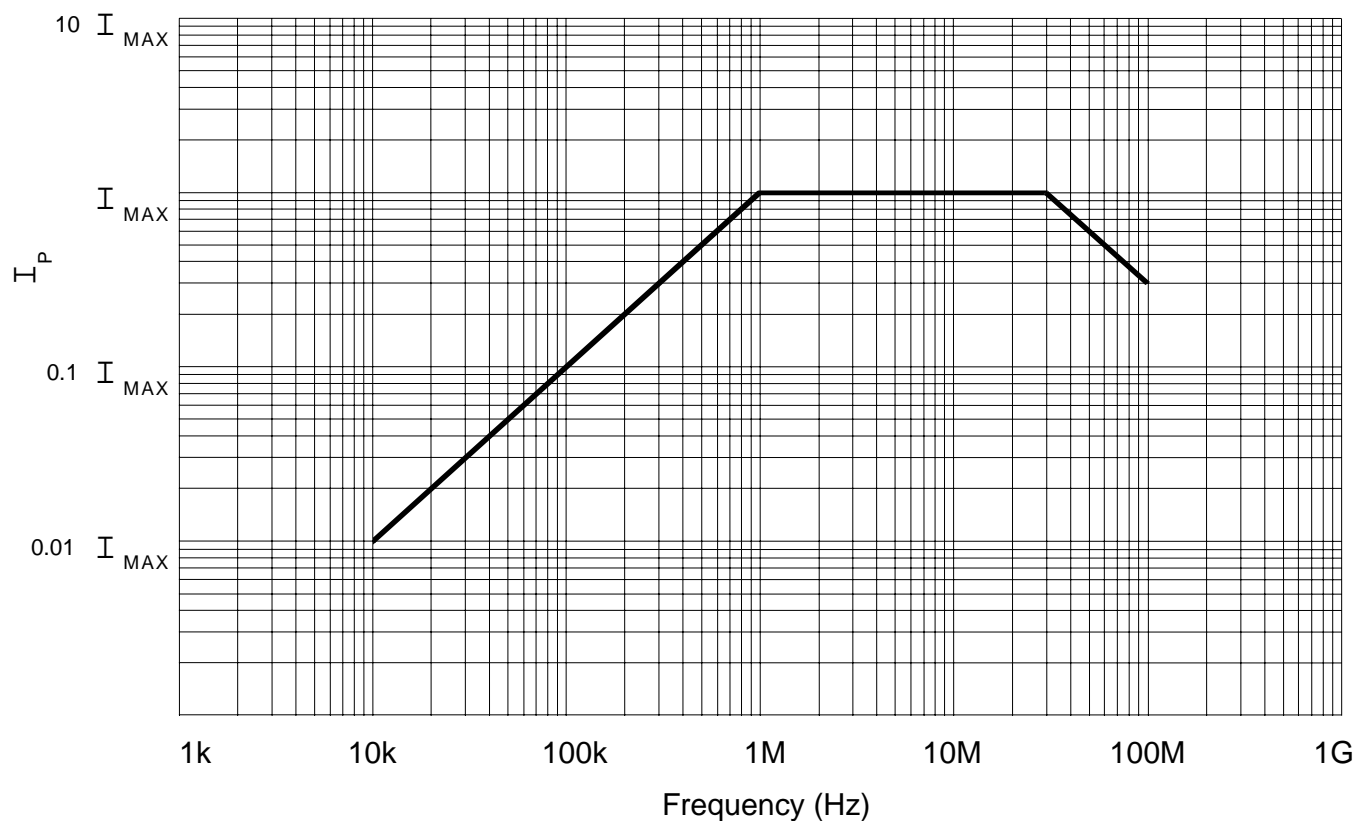
\ln = Natural log

3. I_P as specified in Figure CS116-2

FIGURE CS116-1. Typical CS116 damped sinusoidal waveform.

CS116

| | | |
|--|-----------------|------------------------|
| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
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NOTES:

1. For Army and Navy procurements, $I_{MAX} = 10$ amperes
2. For Air Force procurements, $I_{MAX} = 5$ amperes

FIGURE CS116-2. CS116 limit for all applications.

| | | |
|--|-----------------|------------------------|
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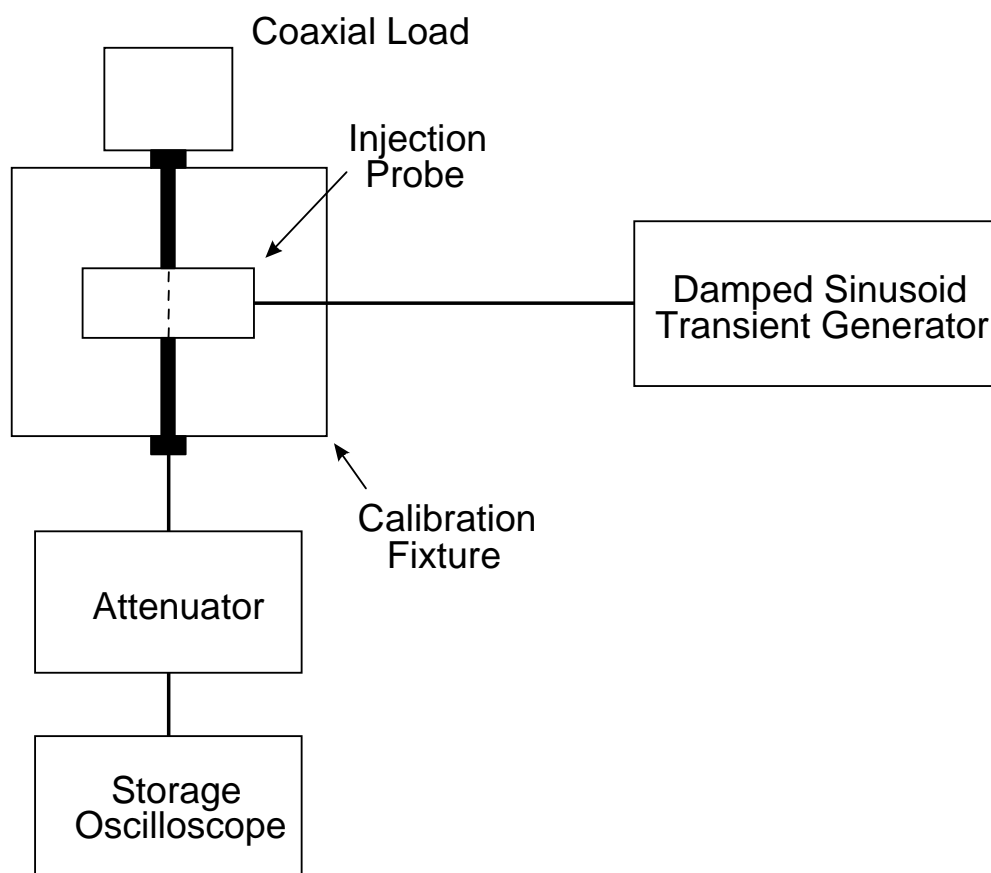


FIGURE CS116-3. Typical test setup for calibration of test waveform ≤ 10 MHz.

| | | |
|--|-----------------|------------------------|
| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
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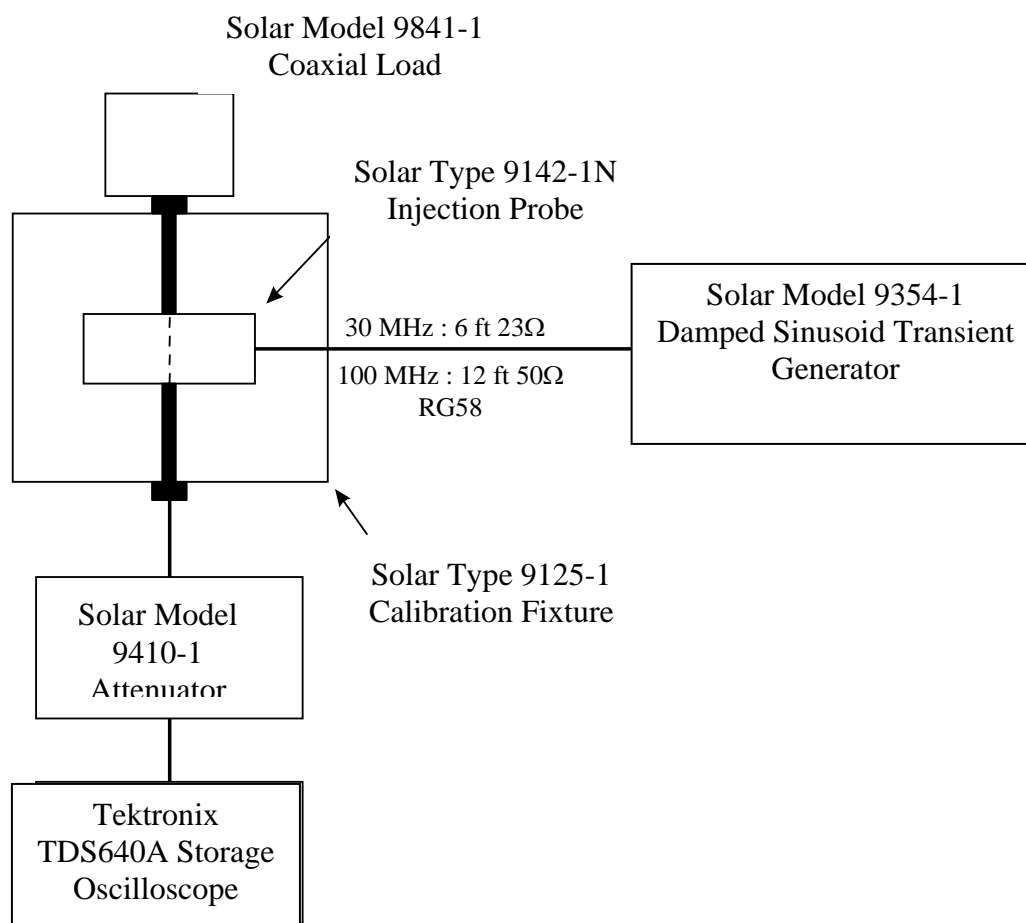


FIGURE CS116-4. Typical test setup for calibration of test waveform > 10 MHz.

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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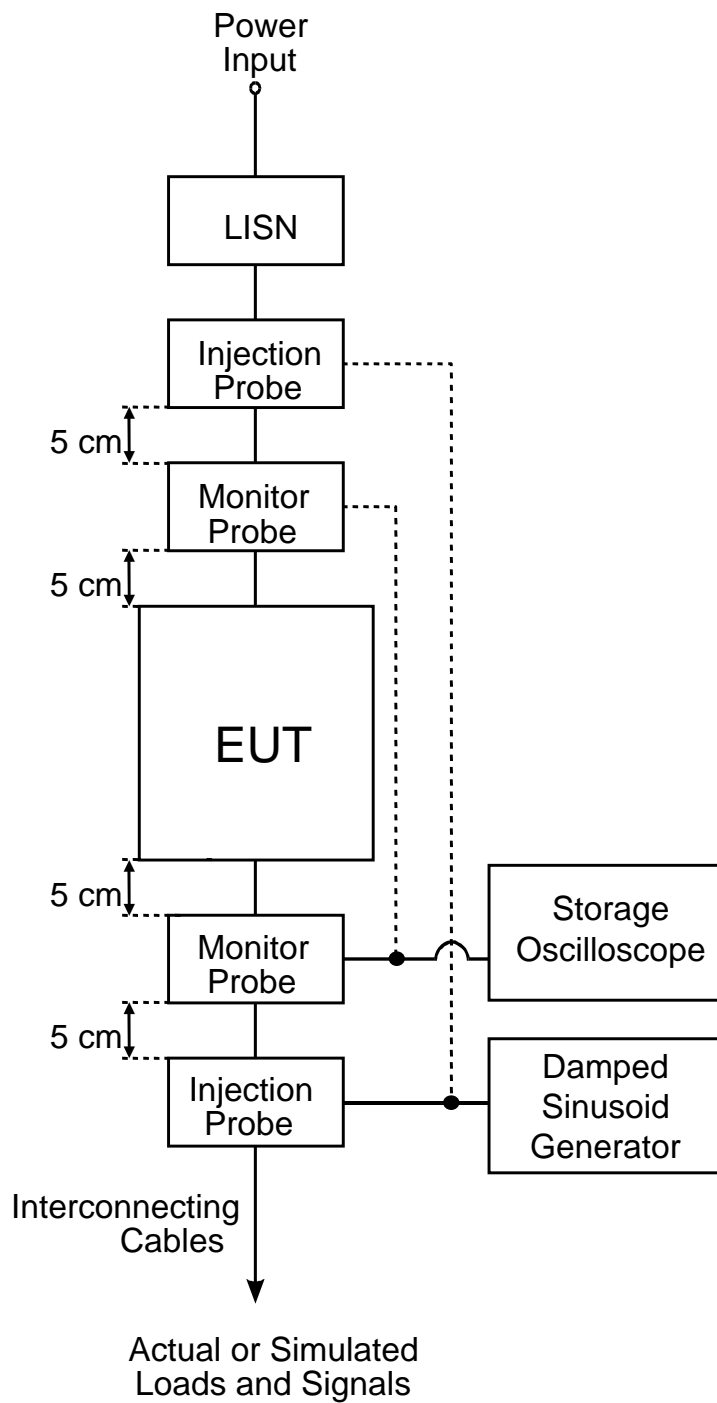


FIGURE CS116-4. Typical set up for bulk cable injection of damped sinusoidal transients.

| | | |
|--|-----------------|------------------------|
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5.15 RE101, Radiated emissions, magnetic field, 30 Hz to 100 kHz.

5.15.1 RE101 applicability.

This requirement is applicable for radiated emissions from equipment and subsystem enclosures, including electrical cable interfaces. The requirement does not apply to radiation from antennas. For Navy aircraft, this requirement is applicable only for aircraft with an ASW capability.

5.15.2 RE101 limit.

Magnetic field emissions shall not be radiated in excess of the levels shown in Figures RE101-1 and RE101-2 at a distance of 7 centimeters.

5.15.3 RE101 test procedures.

5.15.3.1 Purpose.

This test procedure is used to verify that the magnetic field emissions from the EUT and its associated electrical interfaces do not exceed specified requirements.

5.15.3.2 Test Equipment.

The test equipment shall be as follows:

Table RE101-1. METF RE101 Equipment.

| Item | METF Equipment |
|---|---|
| Measurement receiver | Rohde&Schwarz ESI measurement receiver, 20Hz-26.5GHz, or equivalent |
| Data recording device | Personal computer functioning as data recording device |
| Loop sensor with following properties: 13.3 cm diameter 36 turns 7-41 Litz wire Electrostatic shielding | EMCO Model 7604 loop antenna |
| Signal Generator | Agilent 33220A, 0.1mHz-15MHz, or equivalent |
| Ohmmeter | Fluke DMM or equivalent |
| LISN (Positive Lead) | Solar MIL-STD-461E LISN Model # _____ |
| LISN (Return Lead) | Solar MIL-STD-461E LISN Model # _____ |
| Test Software | Total Integrated Laboratory Environment (TILE), or equivalent |
| | |
| | |

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5.15.3.3 Setup.

The test setup shall be as follows:

- Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and 4.3.8.
- Calibration. Configure the measurement setup as shown in Figure RE101-3.
- EUT Testing. Configure the measurement receiving loop and EUT as shown in Figure RE101-4.

5.15.3.4. Procedures.

The test procedures shall be as follows:

- Turn on the measurement equipment and allow sufficient time for stabilization.
- Calibration.
 - Apply a calibrated signal level, which is at least 6 dB below the limit (limit minus the loop sensor correction factor), at a frequency of 50 kHz. The EMCO 7604 loop antenna correction factor is 23.9 dB(pT/uV) at 50kHz. Tune the measurement receiver to a center frequency of 50 kHz. Record the measured level in Table RE101-2.
 - Verify that the measurement receiver indicates a level within ± 3 dB of the injected signal level.
 - If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.
 - Using an ohmmeter, verify that the resistance of the loop sensor winding is approximately 10 ohms and record the value.

Measured resistance: _____ ohm

- Record any deviations from the standard RE101 calibration procedure on RE101 deviation page(s) as needed.

Table RE101-2. Calibration Level

| Frequency (Hz) | MIL-STD-461E Army Limit Level (dBpT) | Limit Level -6dB (dBpT) | Limit Level - 6dB - antenna CF (dBuV) | Signal Injection Level (mVrms) | METF Target Level (dBpT) | Measured Value (dBpT) |
|----------------|--------------------------------------|-------------------------|---------------------------------------|--------------------------------|--------------------------|-----------------------|
| 50k | 116 | 110 | 86.1 | 20.2 | 110 | |

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c. EUT Testing.

- (1) Turn on the EUT and allow sufficient time for stabilization.
- (2) Locate the loop sensor 7 cm from the EUT face or electrical interface connector being probed. Orient the plane of the loop sensor parallel to the EUT faces and parallel to the axis of connectors.
- (3) Scan the measurement receiver over the applicable frequency range to locate the frequencies of maximum radiation, using the bandwidths and minimum measurement times of Table II.
- (4) Tune the measurement receiver to one of the frequencies or band of frequencies identified in 5.15.3.4c(3) above.
- (5) Monitor the output of the measurement receiver while moving the loop sensor (maintaining the 7 cm spacing) over the face of the EUT or around the connector. Note the point of maximum radiation for each frequency identified in 5.15.3.4c(4).
- (6) At 7 cm from the point of maximum radiation, orient the plane of the loop sensor to give a maximum reading on the measurement receiver and record the reading.
- (7) Repeat 5.15.3.4c(4) through 5.15.3.4c(6) for at least two frequencies of maximum radiation per octave of frequencies below 200 Hz and for at least three frequencies of maximum radiation per octave above 200 Hz.
- (8) Repeat 5.15.3.4c(2) through 5.15.3.4c(7) for each face of the EUT and for each EUT electrical connector.

5.15.3.5 Data Presentation.

Data presentation shall be as follows:

- a. Provide graphs of scans.
- b. Record results in the test run log spreadsheet on the METF computer workstation.

| | | |
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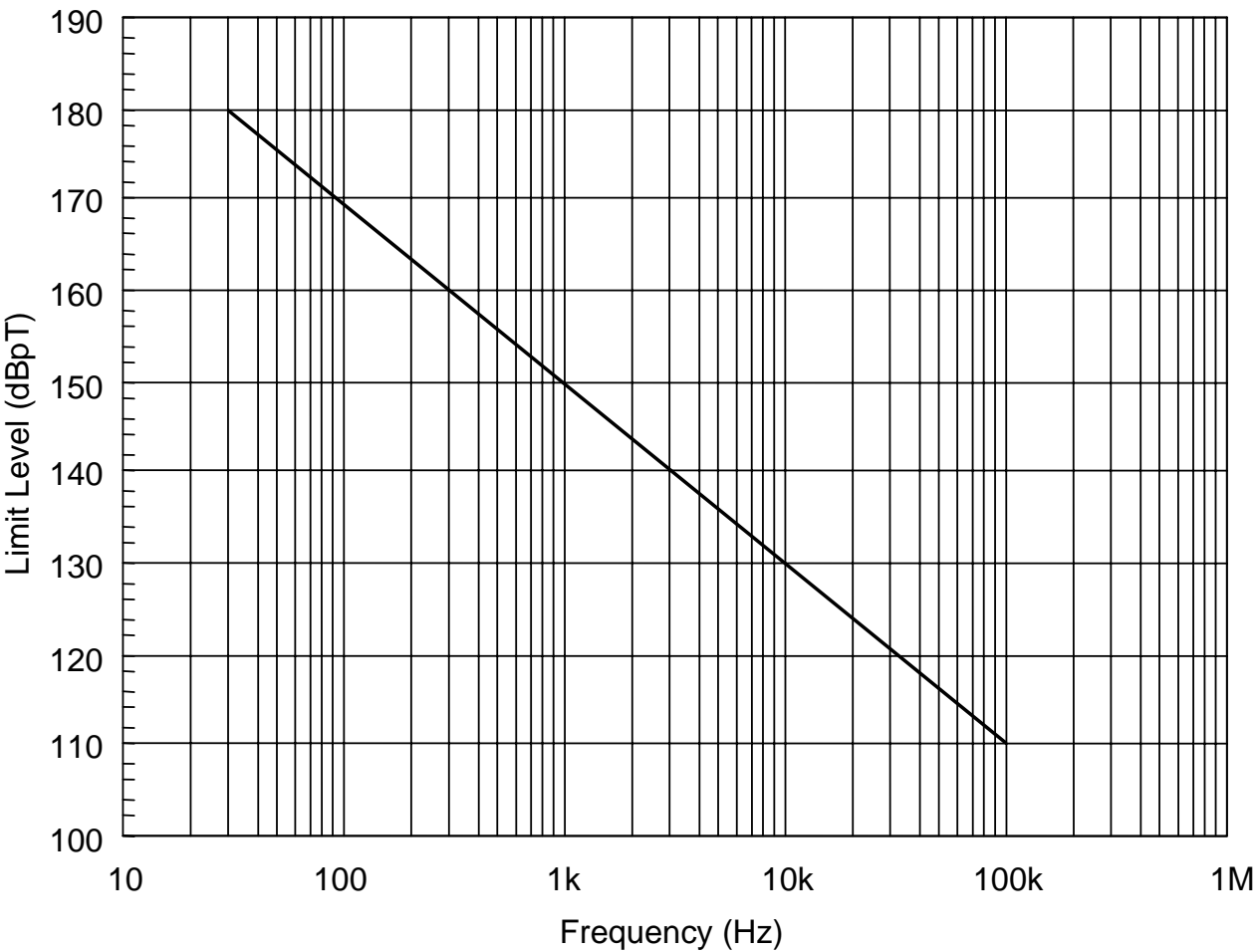


FIGURE RE101-1. RE101 limit for all Army applications.

RE101

| | | |
|--|-----------------|------------------------|
| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
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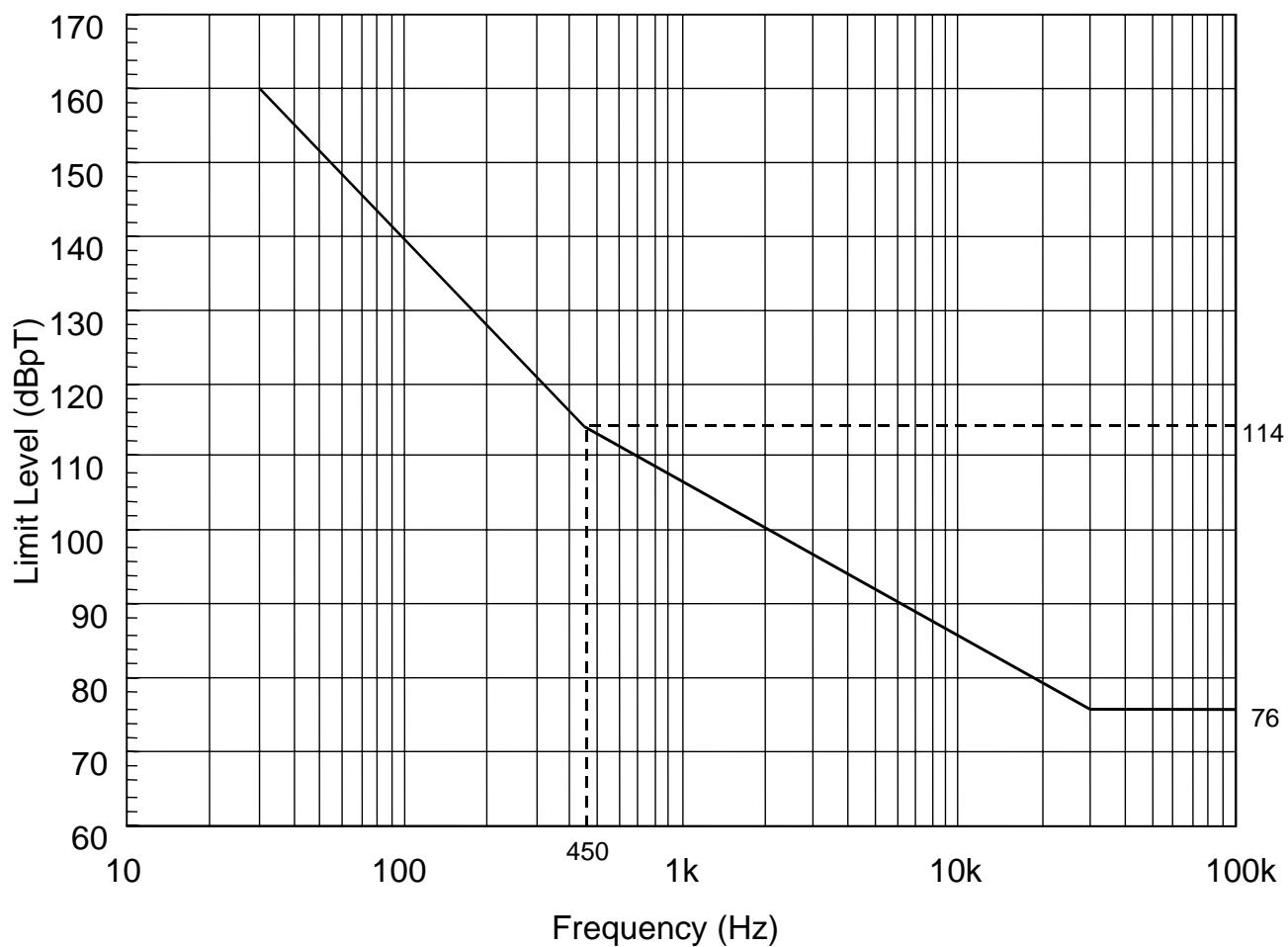


FIGURE RE101-2. RE101 limit for all Navy applications.

RE101

| | | |
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| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
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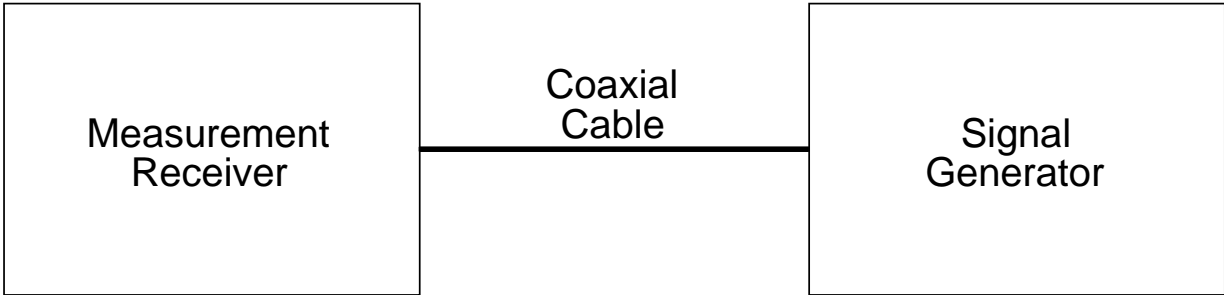


FIGURE RE101-3. Calibration configuration.

| | | |
|--|-----------------|------------------------|
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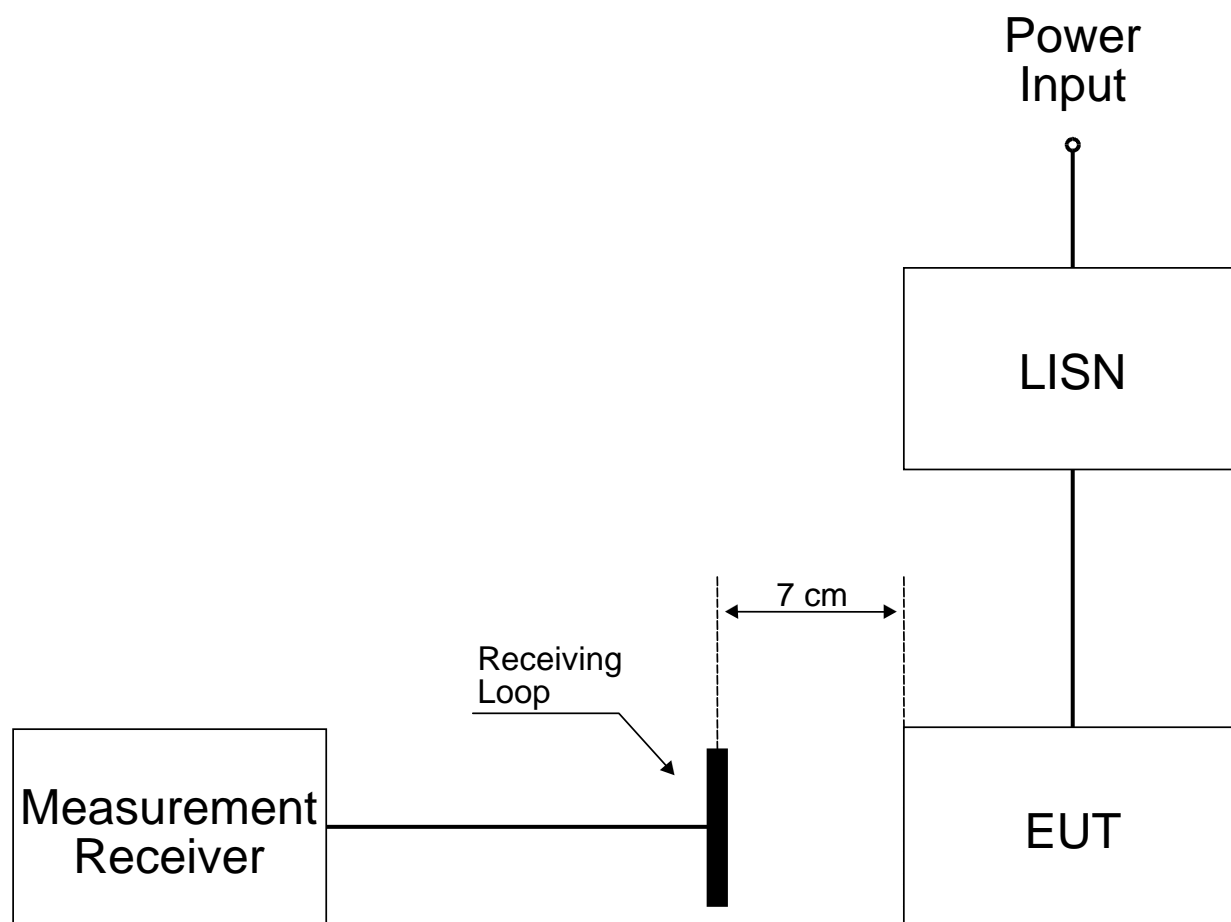


FIGURE RE101-4. Basic test setup.

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5.16 RE102, radiated emissions, electric field, 10 kHz to 18 GHz.

5.16.1 RE102 applicability.

This requirement is applicable for radiated emissions from equipment and subsystem enclosures, all interconnecting cables, and antennas designed to be permanently mounted to EUTs (receivers and transmitters in standby mode). The requirement does not apply at the transmitter fundamental frequencies. The requirement is applicable as follows:

- | | |
|----------------------------------|-------------------|
| a. Ground | 2 MHz to 18 GHz* |
| b. Ships, surface | 10 kHz to 18 GHz* |
| c. Submarines | 10 kHz to 18 GHz* |
| d. Aircraft (Army) | 10 kHz to 18 GHz |
| e. Aircraft (Air Force and Navy) | 2 MHz to 18 GHz* |
| f. Space | 10 kHz to 18 GHz* |

*Testing is required up to 1 GHz or 10 times the highest intentionally generated frequency within the EUT, whichever is greater. Measurements beyond 18 GHz are not required.

5.16.2 RE102 limits.

Electric field emissions shall not be radiated in excess of those shown in Figures RE102-1 through RE102-4. Above 30 MHz, the limits shall be met for both horizontally and vertically polarized fields.

5.16.3 RE102 test procedures.

5.16.3.1 Purpose.

This test procedure is used to verify that electric field emissions from the EUT and its associated cabling do not exceed specified requirements.

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5.16.3.2 Test Equipment.

The test equipment shall be as follows:

Table RE102-1. METF RE102 Equipment.

| Item | METF Equipment | Serial # | Calibration ID | Calibration Due Date |
|--|--|----------|----------------|----------------------|
| Measurement receiver | Rohde&Schwarz ESI measurement receiver, 20Hz-26.5GHz | | | |
| Data recording device | Personal computer functioning as data recording device | N/A | N/A | N/A |
| Test Software | | N/A | N/A | N/A |
| Rod Antenna (10kHz-30MHz) with impedance matching network and 60cmx60cm counterpoise | EMCO Model 3301B 41" rod antenna | | | |
| Biconical Antenna (30MHz-200MHz), 137 cm tip to tip | EMCO Model 3104C or equivalent | | | |
| Double ridge horn (200MHz-1GHz), 69.0cmx94.5cm opening | EMCO Model 3106 or equivalent | | | |
| Double ridge horn (1GHz-18GHz), 24.2cmx13.6cm opening | EMCO Model 3115 or equivalent | | | |
| Preamplifier (30MHz-18GHz) | Rohde&Schwarz Model TS-PR18 | | | |
| Signal Generator (<15MHz) | HP 33120A, 0.1mHz-15MHz, or equivalent | | | |
| Signal Generator (>15MHz) | HP83620B or HP8341B or equivalent | | | |
| Capacitor, 10pF | METF 10pF calibration fixture | N/A | N/A | N/A |
| Comb Generator (10MHz-600MHz) | EMCO Model 4610 or equivalent | | | |
| Double ridge horn (1GHz-18GHz), 24.2cmx13.6cm | EMCO Model 3115 or equivalent | | | |

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| | | | | |
|---------------------------------------|---|--|--|--|
| opening for checking horn antennas | | | | |
| LISN (Positive Lead) | Solar MIL-STD-461E LISN Model # _____ | | | |
| LISN (Return Lead) | Solar MIL-STD-461E LISN Model # _____ | | | |
| | | | | |
| | | | | |
| | | | | |

5.16.3.3 Setup.

The test setup shall be as follows:

- a. Maintain a basic test setup for the EUT as shown and described in Figures 1 through 5 and 4.3.8. Ensure that the EUT is oriented such that the surface that produces the maximum radiated emissions is toward the front edge of the test setup boundary.
- b. Calibration. Configure the test equipment as shown in Figure RE102-5. Record any deviations from the standard RE102 setup on RE102 deviation page(s) as needed.
- c. EUT testing.
 - (1) For shielded room measurements, electrically bond the rod antenna counterpoise to the ground plane using a solid metal sheet that is greater than or equal to the width of the counterpoise. The maximum DC resistance between the counterpoise and the ground plane shall be 2.5 milliohms. For bench top setups using a metallic ground plane, bond the counterpoise to this ground plane. Otherwise, bond the counterpoise to the floor ground plane. For measurements outside a shielded enclosure, electrically bond the counterpoise to earth ground.
 - (2) Antenna Positioning.
 - (a) Determine the test setup boundary of the EUT and associated cabling for use in positioning of antennas.
 - (b) Use the physical reference points on the antennas shown in Figure RE102-6 for measuring heights of the antennas and distances of the antennas from the test setup boundary.
 1. Position antennas 1 meter from the front edge of the test setup boundary for all setups.
 2. Position antennas other than the 104 cm rod antenna 120 cm above the floor ground plane.

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3. Ensure that no part of any antenna is closer than 1 meter from the walls and 0.5 meter from the ceiling of the shielded enclosure.
 4. For test setups using bench tops, additional positioning requirements for the rod antenna and distance above the bench ground plane are shown in Figure RE102-6.
 5. For free standing setups, electrically bond and mount the 104 cm rod antenna matching network to the floor ground plane without a separate counterpoise.
- (c) The number of required antenna positions depends on the size of the test setup boundary and the number of enclosures included in the setup.
1. For testing below 200 MHz, use the following criteria to determine the individual antenna positions.
 - a. For setups with the side edges of the boundary 3 meters or less, one position is required and the antenna shall be centered with respect to the side edges of the boundary.
 - b. For setups with the side edges of the boundary greater than 3 meters, use multiple antenna positions at spacings as shown in Figure RE102-7. Determine the number of antenna positions (N) by dividing the edge-to-edge boundary distance (in meters) by 3 and rounding up to an integer.
 2. For testing from 200 MHz up to 1 GHz, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 35 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.
 3. For testing at 1 GHz and above, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 7 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.
- (3) Record any deviation from the standard RE102 setup on RE102 deviation page(s) as needed.

5.16.3.4 Procedures.

The test procedures shall be as follows:

- a. Verify that the ambient requirements specified in 4.3.4 are met. Take plots of the ambient when required by the referenced paragraph.
- b. Turn on the measurement equipment and allow a sufficient time for stabilization.
- c. Using the system check path of Figure RE102-5, perform the following evaluation of the overall measurement system from each antenna to the data output device at the highest measurement frequency of the antenna. For rod antennas that use passive

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matching networks, the evaluation shall be performed at the center frequency of each band. For active rod antennas, the evaluation shall be performed at the lowest frequency of test, at a mid-band frequency, and at the highest frequency of test.

- (1) Apply a calibrated signal level, which is at least 6 dB below the limit (limit minus antenna factor), to the coaxial cable at the antenna connection point.
- (2) Scan the measurement receiver in the same manner as a normal data scan. Verify that the data recording device indicates a level within ± 3 dB of the injected signal level.
- (3) For the 104 cm rod antenna, remove the rod element and apply the signal to the antenna matching network through a 10 pF capacitor connected to the rod mount.
- (4) Record the measured values in column 7 of Table RE102-2.
- (5) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.
- (6) Record any deviations from the standard RE102 calibration procedure on RE102 deviation page(s) as needed.

Table RE102-2. Calibration Levels

| Frequency (Hz) | MIL-STD-461E RE102 Limit Level (dB μ V/m) | Limit Level –6dB (dB μ V/m) | Limit Level – 6dB- Antenna CF (dB μ V) | Signal Injection Level (mVrms) | METF Target Level (dB μ V/m) | Measured Value (dB μ V/m) |
|-------------------|--|---------------------------------------|---|---|---|----------------------------------|
| 10k | | | | | | |
| 5M | | | | | | |
| 30M | | | | | | |
| 200M | | | | | | |
| 1G | | | | | | |
| 18G | | | | | | |

- d. Using the measurement path of Figure RE102-5, perform the following evaluation for each antenna to demonstrate that there is electrical continuity through the antenna.
 - (1) Radiate a signal using an antenna or stub radiator at the highest measurement frequency of each antenna.
 - (2) Tune the measurement receiver to the frequency of the applied signal and verify that a received signal of appropriate amplitude is present. Note: This evaluation is

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intended to provide a coarse indication that the antenna is functioning properly. There is no requirement to accurately measure the signal level. Record the verification results in Table RE102-3.

Table RE102-3. Antenna check results

| Frequency (Hz) | Antenna Continuity (Yes/No) |
|-------------------|-----------------------------------|
| 30M | |
| 200M | |
| 1G | |
| 18G | |

- e. Turn on the EUT and allow sufficient time for stabilization.
- f. Using the measurement path of Figure RE102-5, determine the radiated emissions from the EUT and its associated cabling.
 - (1) Scan the measurement receiver for each applicable frequency range, using the bandwidths and minimum measurement times in Table II.
 - (2) Above 30 MHz, orient the antennas for both horizontally and vertically polarized fields.
 - (3) Take measurements for each antenna position determined under 5.16.3.3c(2)(c) above.
- g. Record any deviations from the standard RE102 EUT test procedure on RE102 deviation page(s) as needed.

5.16.3.5 Data Presentation.

Data presentation shall be as follows:

- a. Continuously and automatically plot amplitude versus frequency profiles. Manually gathered data is not acceptable except for plot verification. Vertical and horizontal data for a particular frequency range shall be presented on separate plots or shall be clearly distinguishable in black or white format for a common plot.
- b. Display the applicable limit on each plot.
- c. Provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less stringent, and a minimum amplitude resolution of 1 dB for each plot.

| | | |
|--|-----------------|------------------------|
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- d. Provide plots for both the measurement and system check portions of the procedure.
- e. Complete Table RE102-3 to prove the electrical continuity of the measurement antennas as determined in 5.16.3.4d.
- f. Record results in Table RE102-4.

EUT: _____

| Run/Data Plot Number | Pass/Fail | Overlimit Amplitudes and Frequencies | EUT Configuration |
|----------------------|-----------|--------------------------------------|-------------------|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

Table RE102-4. RE102 Test Results

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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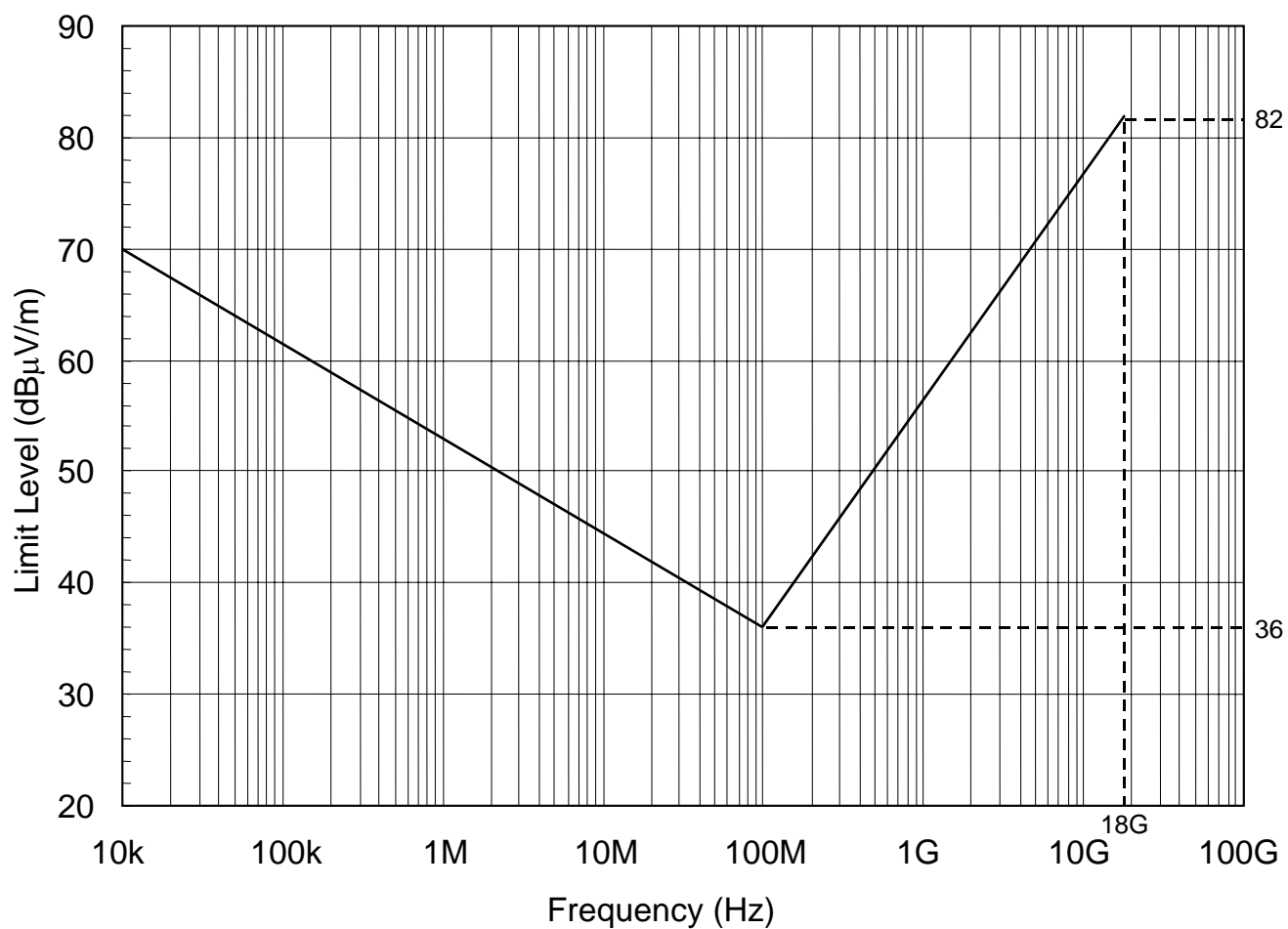


FIGURE RE102-1. RE102 limit for surface ship applications.

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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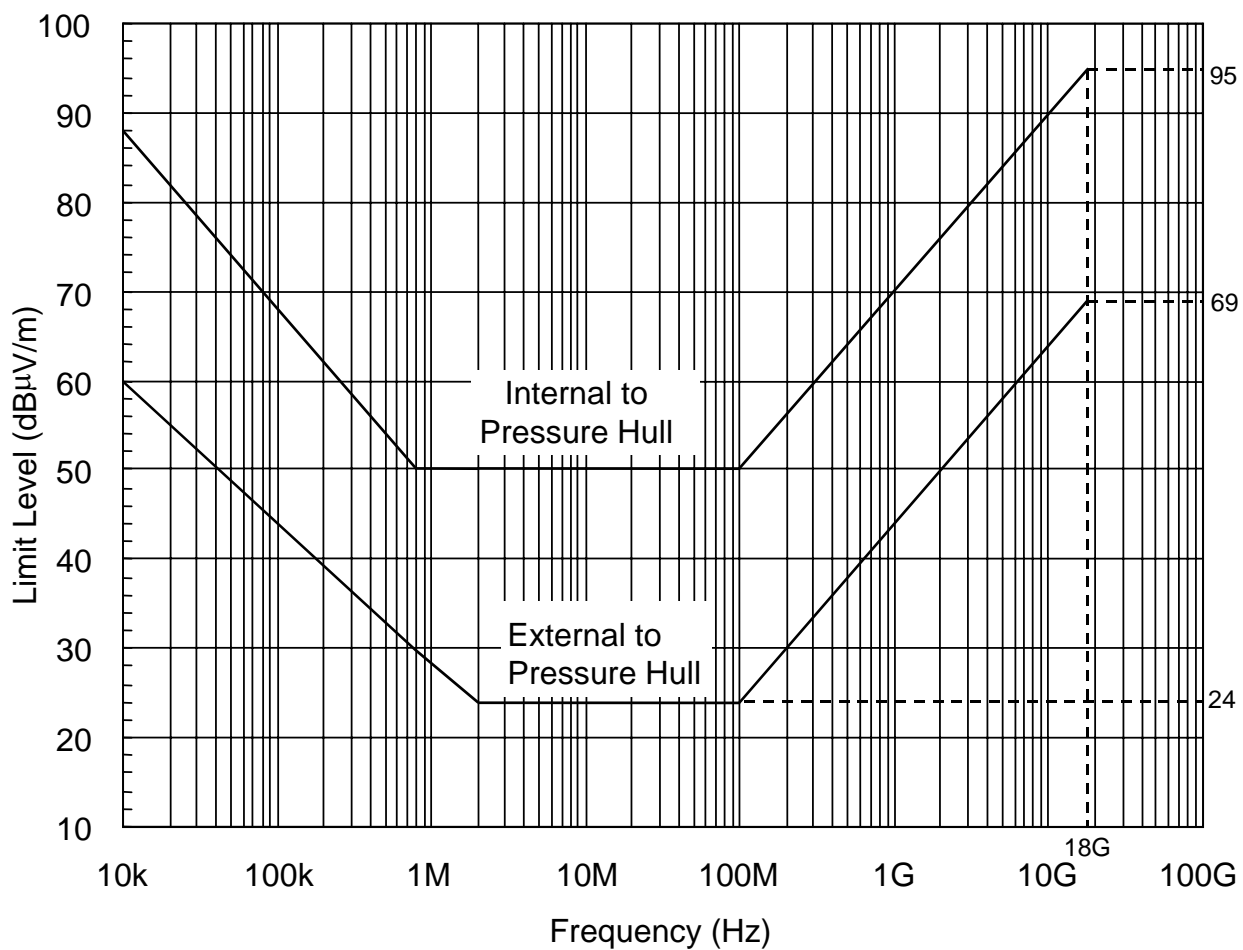


FIGURE RE102-2. RE102 limit for submarine applications.

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
| MIL-STD-461E EMI Testing | MFOP-FA-EMI-30X | Revision: ROUGH DRAFT4 |
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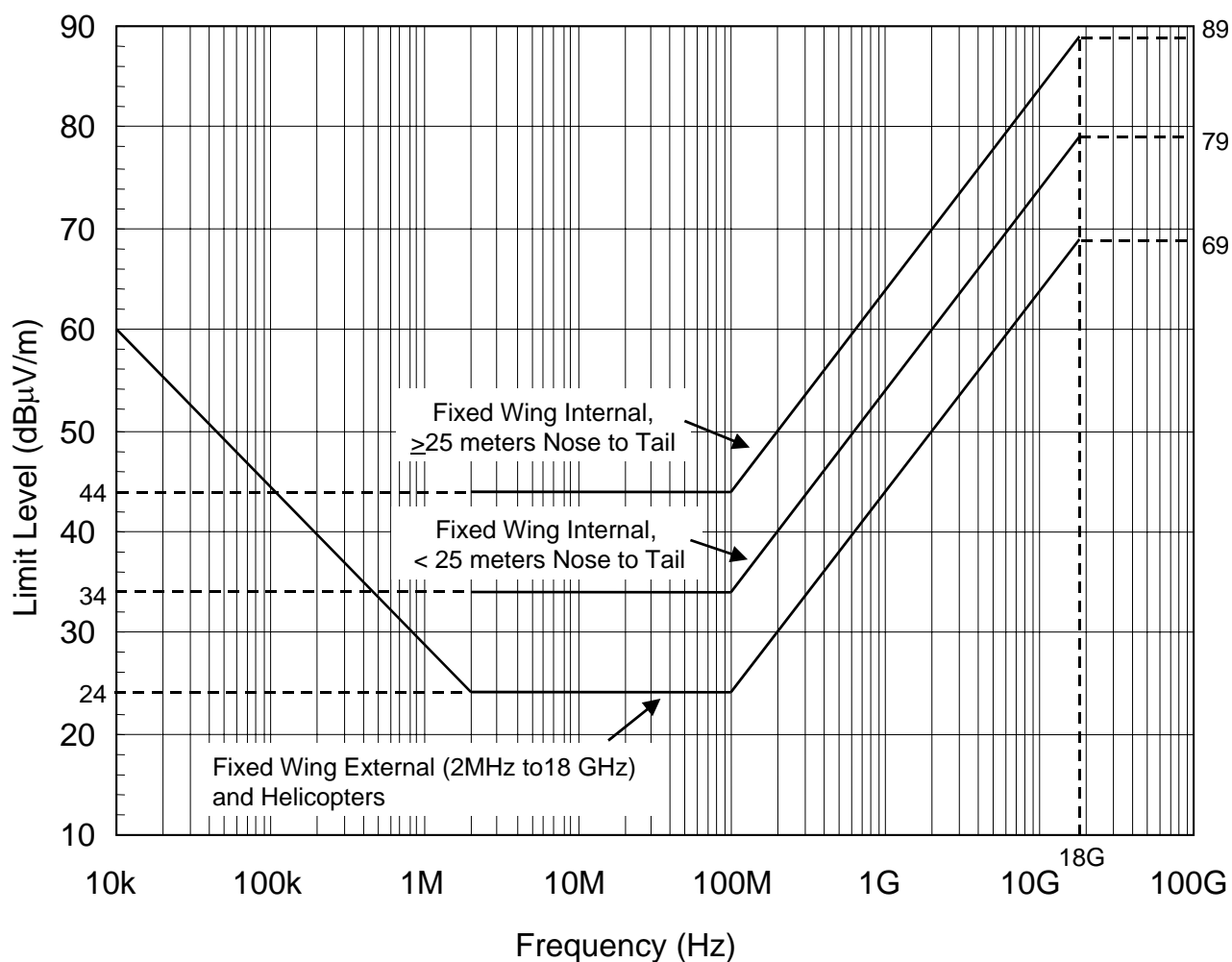


FIGURE RE102-3. RE102 limit for aircraft and space system applications.

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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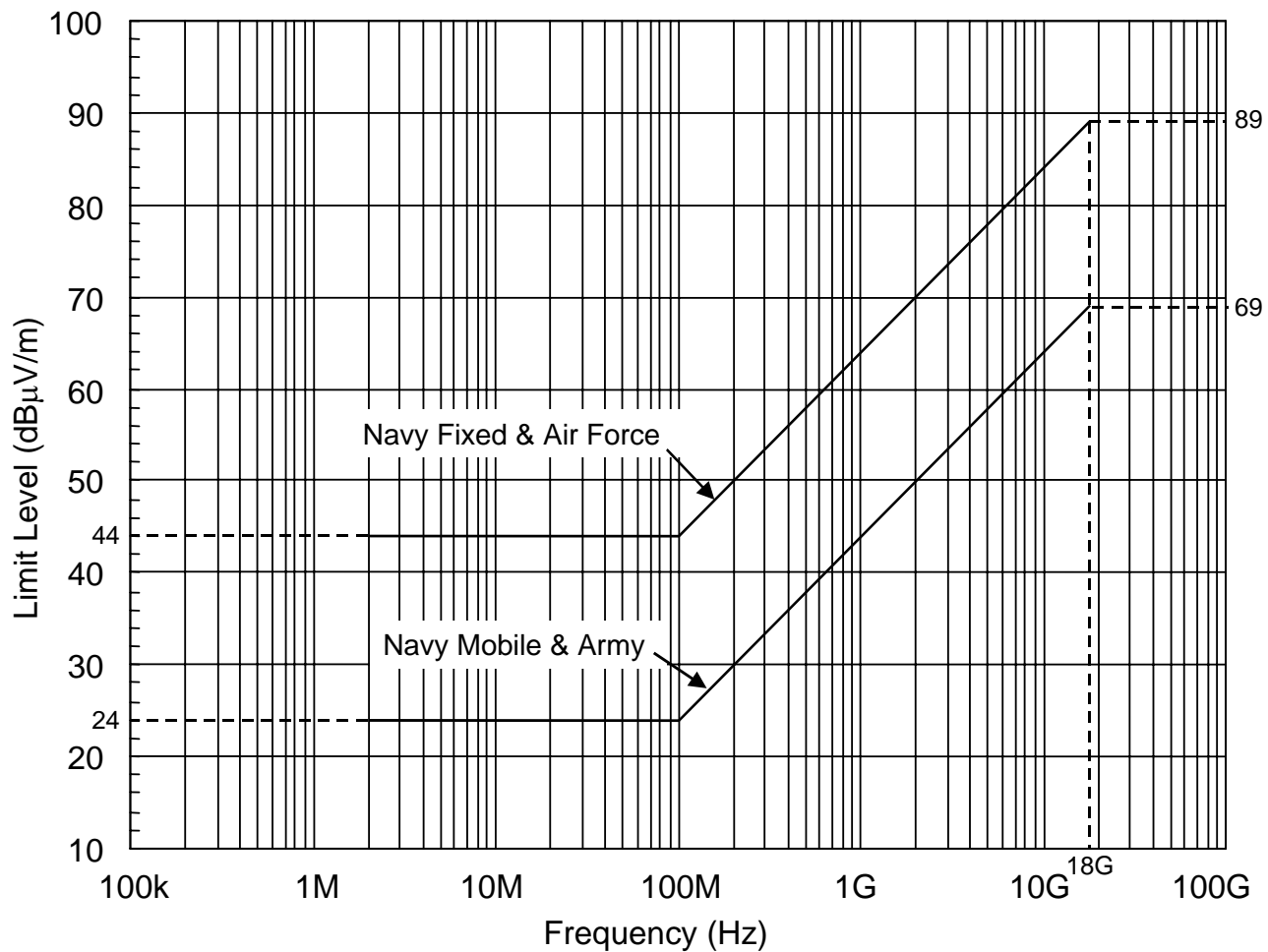


FIGURE RE102-4. RE102 limit for ground applications.

| | | |
|--|-----------------|------------------------|
| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
| MIL-STD-461E EMI Testing | MFOP-FA-EMI-30X | Revision: ROUGH DRAFT4 |
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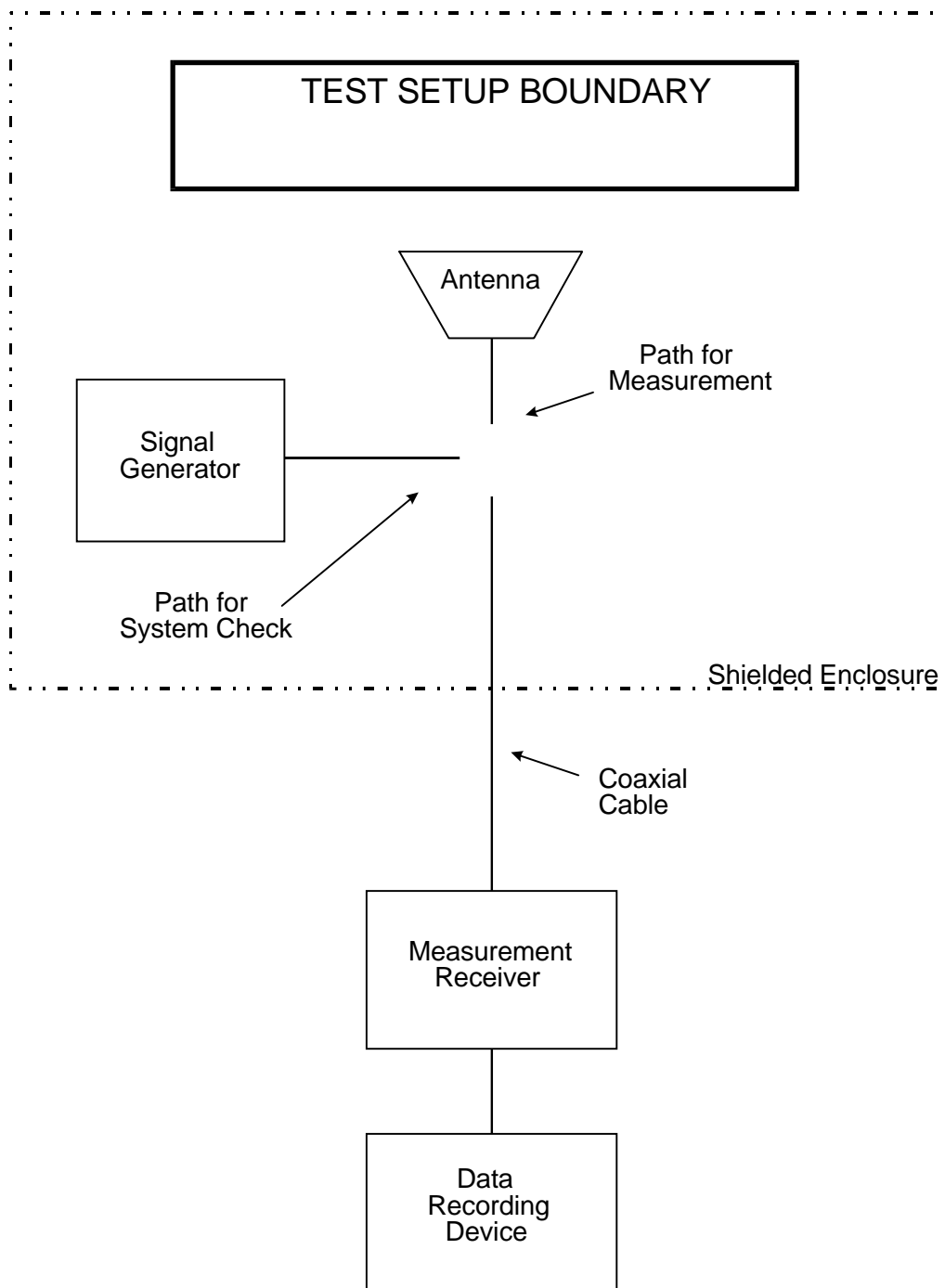


FIGURE RE102-5. Basic test setup.

| | | |
|--|-----------------|------------------------|
| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
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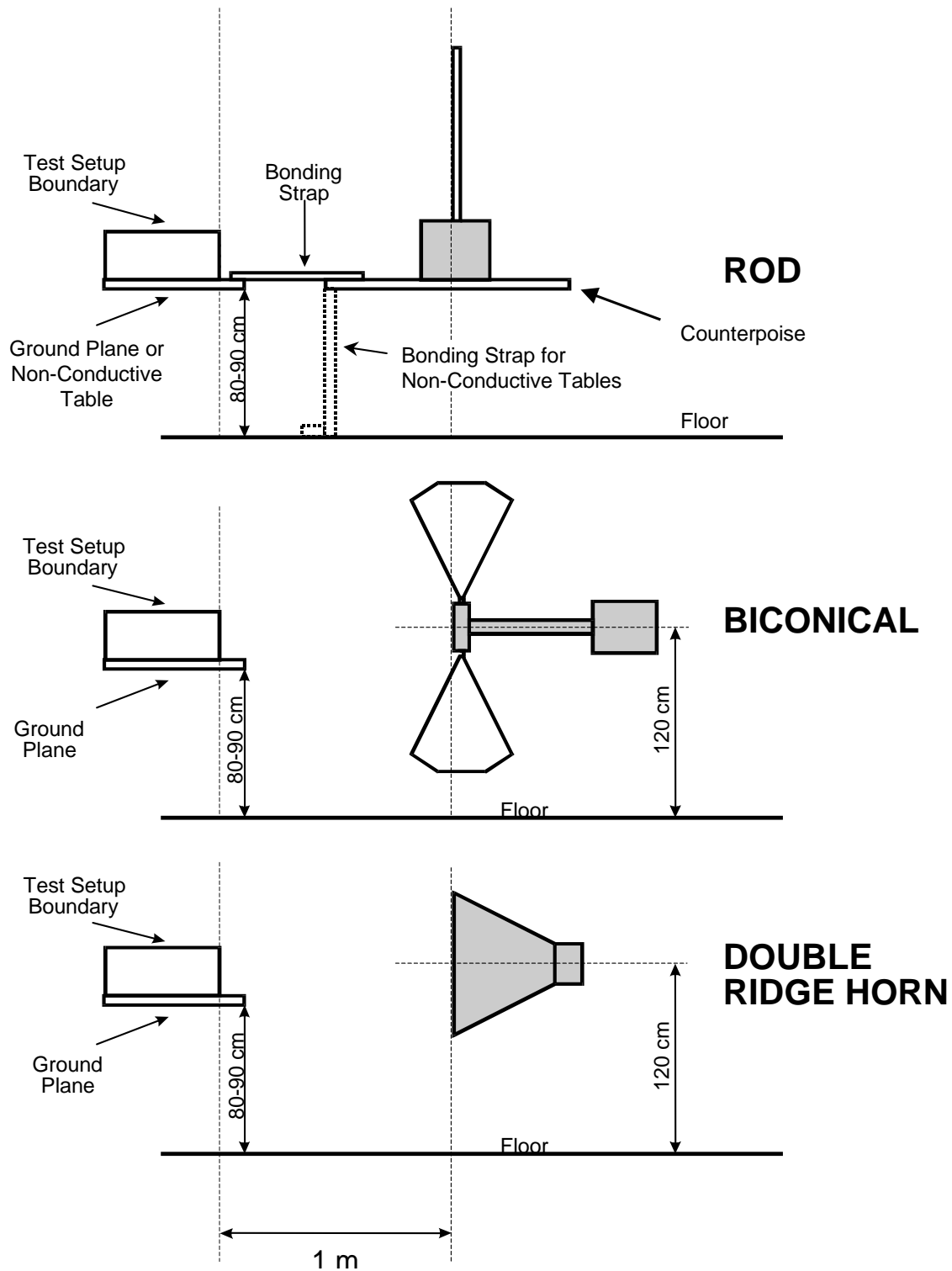


FIGURE RE102-6. Antenna positioning.

| | | |
|--|-----------------|------------------------|
| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
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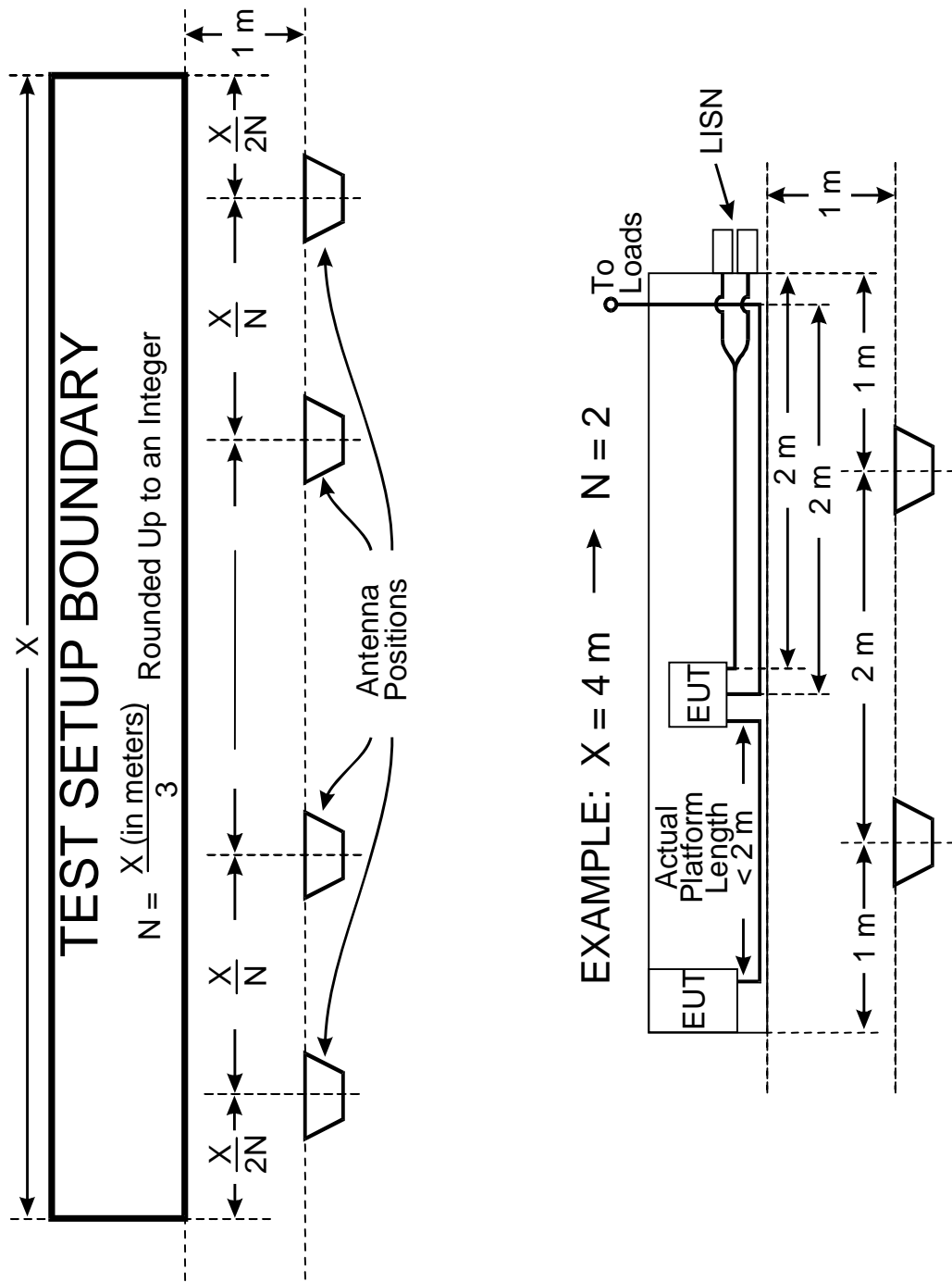


FIGURE RE102-7. Multiple antenna positions.

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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5.17 RS101, radiated susceptibility, magnetic field, 30 Hz to 100 kHz.

5.17.1 RS101 applicability.

This requirement is applicable to equipment and subsystem enclosures, including electrical cable interfaces. The requirement is not applicable for electromagnetic coupling via antennas. For equipment intended to be installed on Navy aircraft, the requirement is applicable only to aircraft with ASW capability. For Army ground equipment, the requirement is applicable only to vehicles having a minesweeping or mine detection capability.

5.17.2 RS101 limit.

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to the magnetic fields shown in Figures RS101-1 and RS101-2.

5.17.3 RS101 test procedures.

5.17.3.1 Purpose.

This test procedure is used to verify the ability of the EUT to withstand radiated magnetic fields.

5.17.3.2 Test Equipment.

The test equipment shall be as follows:

- a. Signal source
- b. Radiating loop having the following specifications:
 - (1) Diameter: 12 cm
 - (2) Number of turns: 20
 - (3) Wire: No. 12 insulated copper
 - (4) Magnetic flux density: 9.5×10^7 pT/ampere of applied current at a distance of 5 cm from the plane of the loop.
- c. Loop sensor having the following specifications:
 - (1) Diameter: 4 cm
 - (2) Number of turns: 51
 - (3) Wire: 7-41 Litz wire (7 Strand, No. 41 AWG)
 - (4) Shielding: Electrostatic
 - (5) Correction Factor: See manufacturer's data for factors to convert measurement receiver readings to decibels above one picotesla (dBpT).
- d. Measurement receiver or narrowband voltmeter
- e. Current probe
- f. LISNs

5.17.3.3 Setup.

The test setup shall be as follows:

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|--|-----------------|------------------------|
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- a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and 4.3.8.
- b. Calibration. Configure the measurement equipment, radiating loop, and loop sensor as shown in Figure RS101-3.
- c. EUT Testing. Configure the test as shown in Figure RS101-4.

5.17.3.4 Procedures.

The test procedures shall be as follows:

- a. Turn on the measurement equipment and allow sufficient time for stabilization.
- b. Calibration.
 - (1) Set the signal source to a frequency of 1 kHz and adjust the output to provide a magnetic flux density of 110 dB above one picotesla as determined by the reading obtained on measurement receiver A and the relationship given in 5.18.3.2b(4).
 - (2) Measure the voltage output from the loop sensor using measurement receiver B.
 - (3) Verify that the output on measurement receiver B is within ± 3 dB of the expected value based on the antenna factor and record this value.
- c. EUT Testing.
 - (1) Turn on the EUT and allow sufficient time for stabilization.
 - (2) Select test frequencies as follows:
 - (a) Locate the loop sensor 5 cm from the EUT face or electrical interface connector being probed. Orient the plane of the loop sensor parallel to the EUT faces and parallel to the axis of connectors.
 - (b) Supply the loop with sufficient current to produce magnetic field strengths at least 10 dB greater than the applicable limit but not to exceed 15 amps (183 dBpT).
 - (c) Scan the applicable frequency range. Scan rates up to 3 times faster than the rates specified in Table III are acceptable.
 - (d) If susceptibility is noted, select no less than three test frequencies per octave at those frequencies where the maximum indications of susceptibility are present.
 - (e) Reposition the loop successively to a location in each 30 by 30 cm area on each face of the EUT and at each electrical interface connector, and repeat 5.18.3.4c(2)(c) and 5.18.3.4c(2)(d) to determine locations and frequencies of susceptibility.
 - (f) From the total frequency data where susceptibility was noted in 5.18.3.4c(2)(c) through 5.18.3.4c(2)(e), select three frequencies per octave over the applicable frequency range.

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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- (3) At each frequency determined in 5.18.3.4c(2)(f), apply a current to the radiating loop that corresponds to the applicable limit. Move the loop to search for possible locations of susceptibility with particular attention given to the locations determined in 5.18.3.4c(2)(e) while maintaining the loop 5 cm from the EUT surface or connector. Verify that susceptibility is not present.

5.17.3.5 Data Presentation.

Data presentation shall be as follows:

- a. Provide tabular data showing verification of the calibration of the radiating loop in 5.18.3.4b.
- b. Provide tabular data, diagrams, or photographs showing the applicable test frequencies and locations determined in 5.18.3.4c(2)(e) and 5.18.3.4c(2)(f).
- c. Provide graphical or tabular data showing frequencies and threshold levels of susceptibility.

5.17.4 RS101 alternative test procedures – AC Helmholtz coil.

This test procedure may be substituted for the 5.18.3 procedures, provided that the EUT size versus coil size constraints of 5.18.4.3b can be satisfied.

5.17.4.1 Purpose.

This test procedure is an alternative technique used to verify the ability of the EUT to withstand radiated magnetic fields.

5.17.4.2 Test Equipment.

The test equipment shall be as follows:

- a. Signal source
- b. Series-wound AC Helmholtz coil
- c. Loop sensor having the following specifications (same as RE101 loop):
 - (1) Diameter: 13.3 cm
 - (2) Number of turns: 36
 - (3) Wire: 7-41 Litz wire (7 strand, No. 41 AWG)
 - (4) Shielding: Electrostatic
 - (5) Correction factor: See manufacturer's data for factors to convert measurement receiver readings to decibels above one picotesla (dBpT).
- d. Measurement receiver or narrowband voltmeter
- e. Current probe
- f. LISNs

5.17.4.3 Setup.

The test setup shall be as follows:

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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- a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and 4.3.8.
- b. Calibration.
 - (1) Configure the radiating system as shown in Figure RS101-5. Select coil spacing based on the physical dimensions of the EUT enclosure.
 - (2) For an EUT with dimensions less than one coil radius, use a standard Helmholtz configuration (coils separated by one coil radius). Place the field monitoring loop in the center of the test volume.
 - (3) For an EUT with dimensions greater than one coil radius, use the optional configuration. Select a coil separation such that the plane of the EUT face is at least 5 cm from the plane of the coils and such that the separation between the coils does not exceed 1.5 radii. Place the field monitoring probe in the plane of either coil at its center.
- c. EUT Testing.
 - (1) Configure the test as shown in Figure RS101-6, using the same coil spacing arrangement as determined for calibration under 5.18.4.3b.
 - (2) Position the coils such that the plane of the EUT faces is in parallel with the plane of the coils.

5.17.4.4 Procedures.

The test procedures shall be as follows:

- a. Turn on the measurement equipment and allow sufficient time for stabilization.
- b. Calibration.
 - (1) Set the signal source to a frequency of 1 kHz and adjust the output current to generate a magnetic flux density of 110 dB above one picotesla as determined by the reading obtained on measurement receiver A.
 - (2) Measure the voltage output from the loop sensor using measurement receiver B.
 - (3) Verify that the output on measurement receiver B is within ± 3 dB of the expected value based on the antenna factor and record this value.
- c. EUT Testing.
 - (1) Turn on the EUT and allow sufficient time for stabilization.
 - (2) Select test frequencies as follows:
 - (a) Supply the Helmholtz coil with sufficient current to produce magnetic field strengths at least 6 dB greater than the applicable limit.
 - (b) Scan the applicable frequency range. Scan rates up to 3 times faster than the rates specified in Table III are acceptable.

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- (c) If susceptibility is noted, select no less than three test frequencies per octave at those frequencies where the maximum indications of susceptibility are present.
 - (d) Reposition the Helmholtz coils successively over all areas on each face of the EUT (in all three axes), including exposure of any electrical interface connectors, and repeat 5.18.4.4c(2)(b) and 5.18.4.4c(2)(c) to determine locations and frequencies of susceptibility.
 - (e) From the total frequency data where susceptibility was noted in 5.18.4.4c(2)(b) through 5.18.4.4c(2)(d), select three frequencies per octave over the applicable frequency range.
- (3) At each frequency determined in 5.18.4.4c(2)(e), apply a current to the Helmholtz coil that corresponds to the applicable RS101 limit. Move the coils to search for possible locations of susceptibility with particular attention given to the locations determined in 5.18.4.4c(2)(d). Ensure the EUT remains centered between the coils, or the coils remain 5 cm from the EUT surface, as applicable. Verify that susceptibility is not present.

5.17.4.5 Data Presentation.

Data presentation shall be as follows:

- a. Provide tabular data showing verification of the calibration of the Helmholtz coils in 5.17.4.4b.
- b. Provide tabular data, diagrams, or photographs showing the applicable test frequencies and locations determined in 5.17.4.4c(2)(d) and 5.17.4.4c(2)(e).
- c. Provide graphical or tabular data showing frequencies and threshold levels of susceptibility.

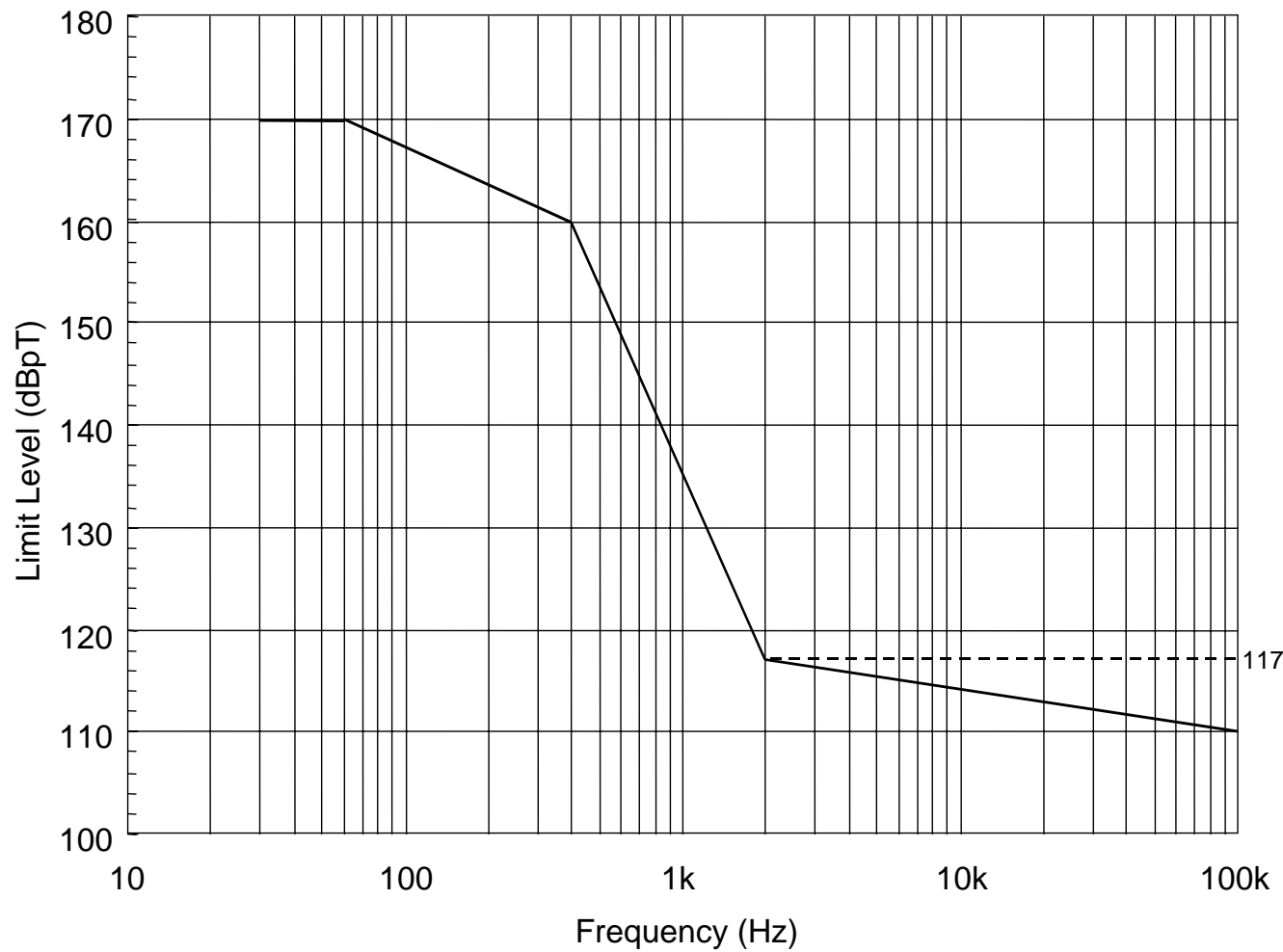


FIGURE RS101-1. RS101 limit for all Navy applications.

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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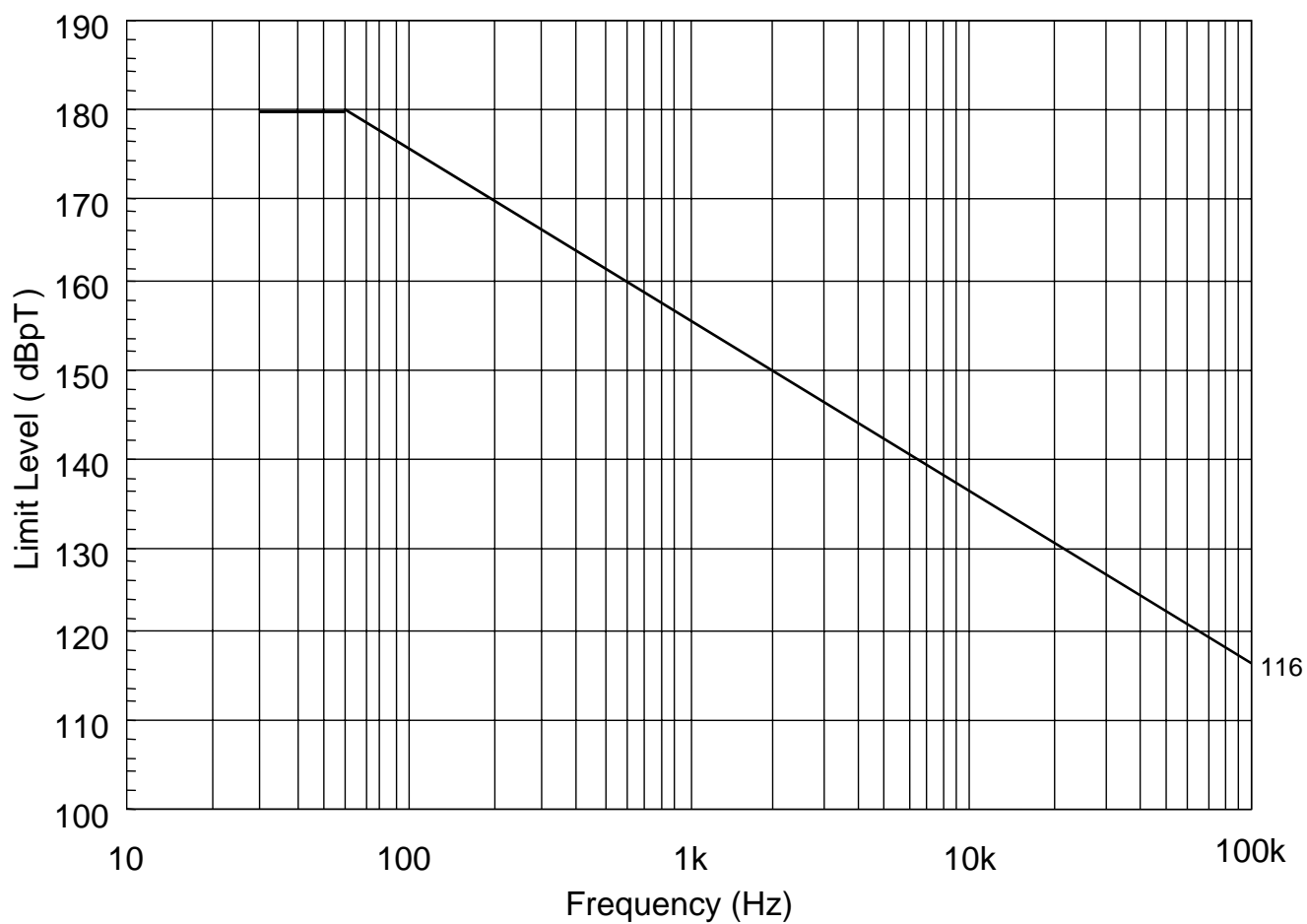


FIGURE RS101-2. RS101 limit for all Army applications.

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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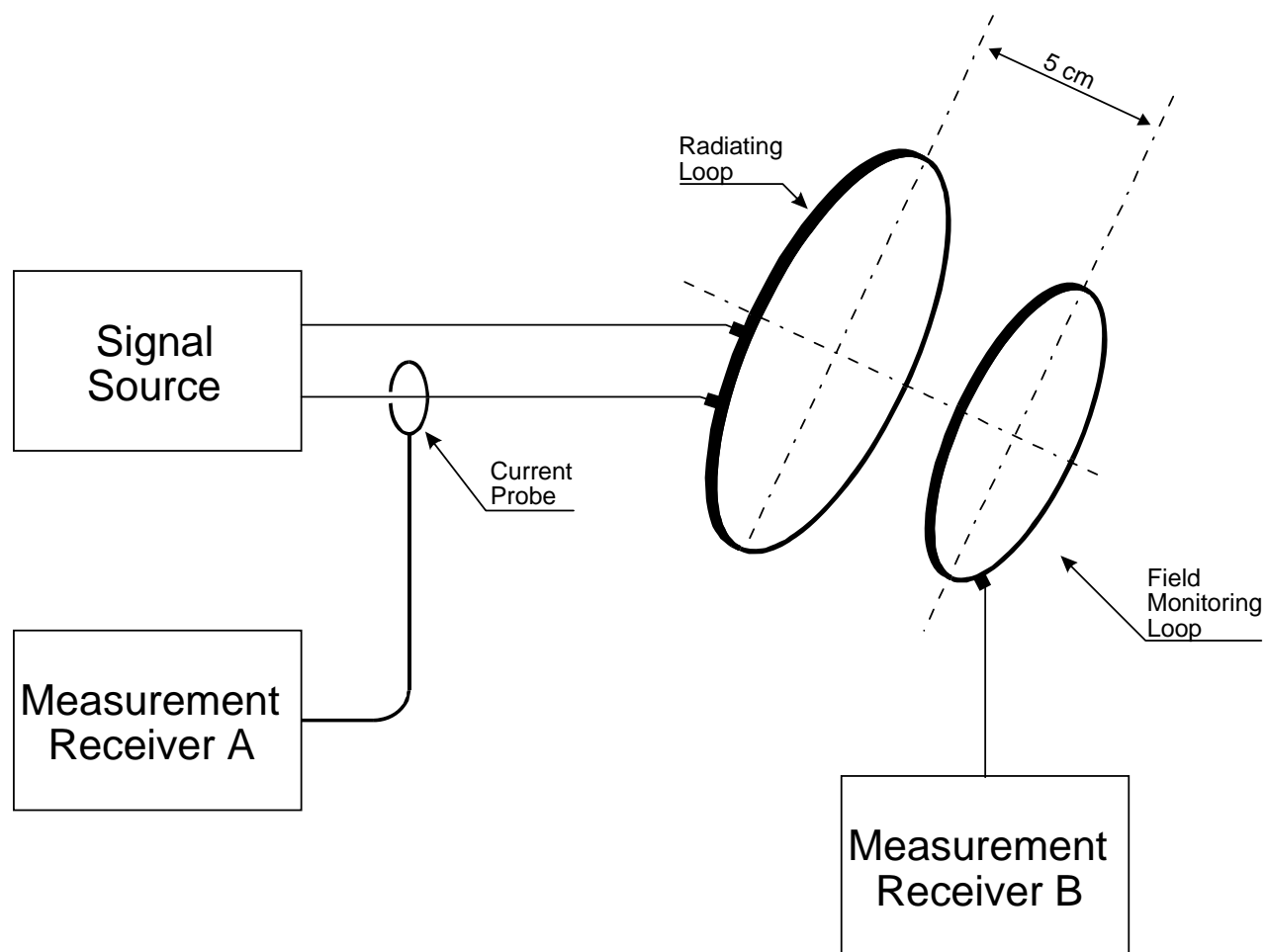


FIGURE RS101-3. Calibration of the radiating system.

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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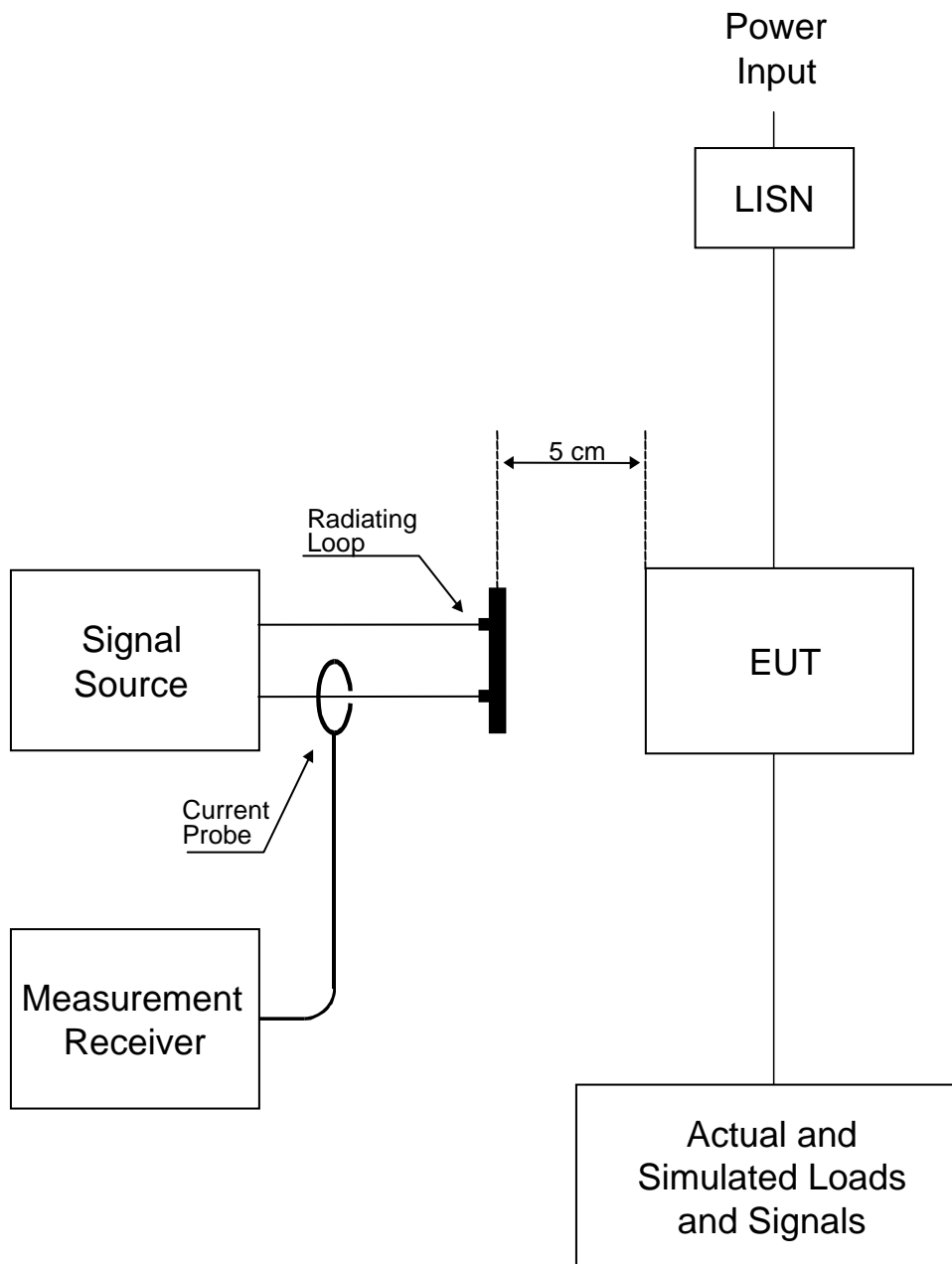
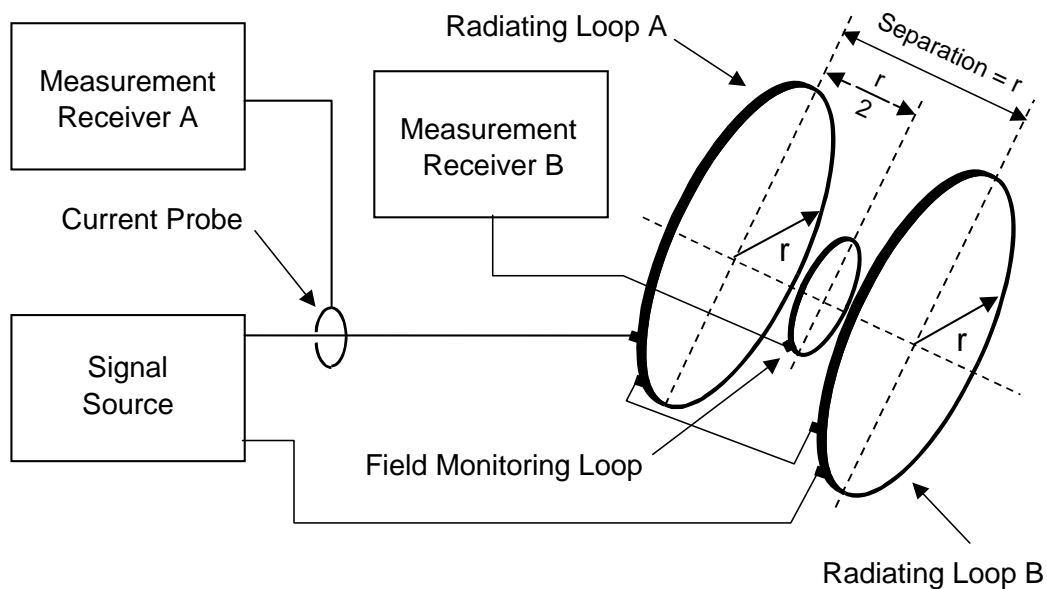
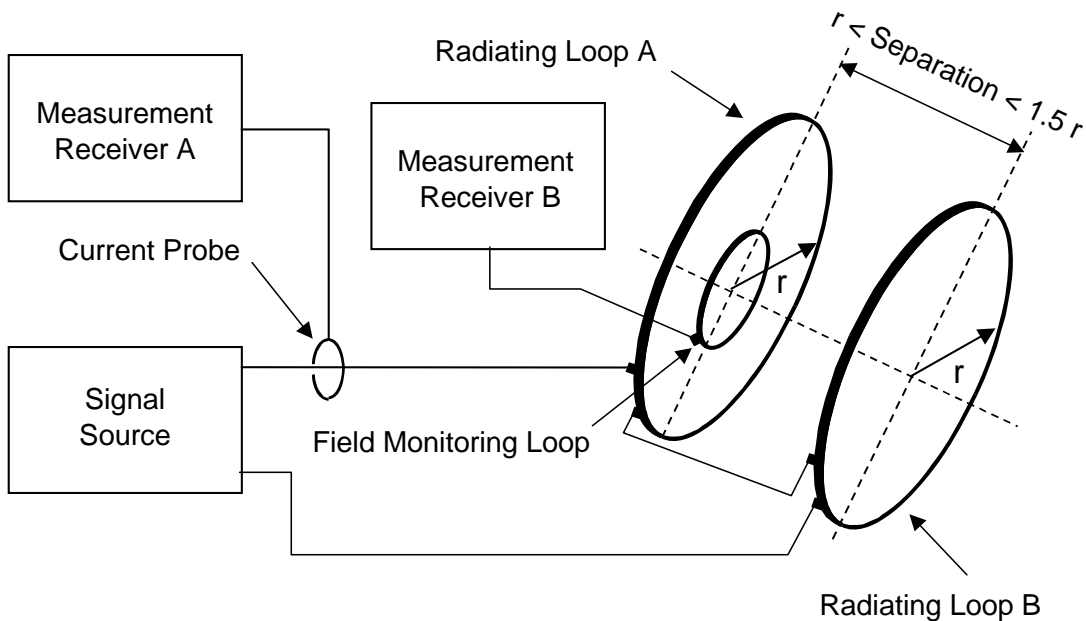


FIGURE RS101-4. Basic test setup

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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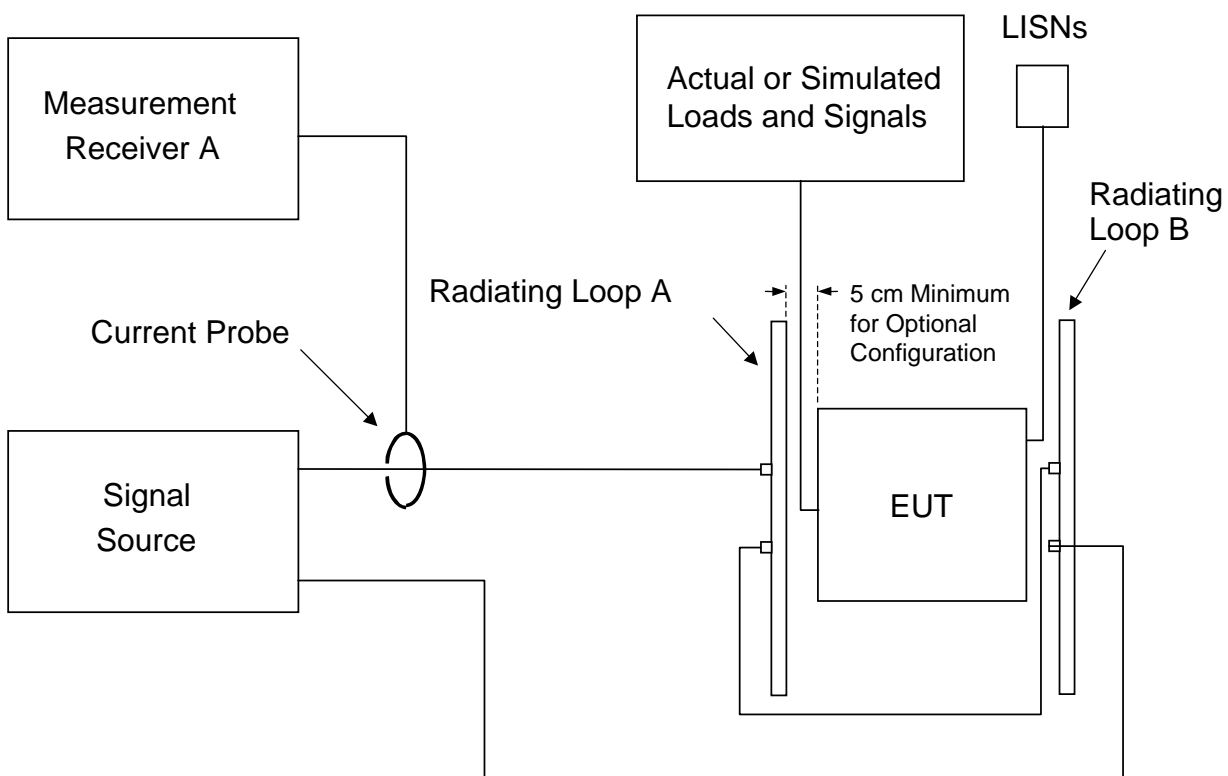
Standard Configuration



Optional Configuration

FIGURE RS101-5. Calibration of Helmholtz coils

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|--|-----------------|------------------------|
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Note: One axis position of three required is shown

FIGURE RS101-6. Test setup for Helmholtz coils.

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|--|-----------------|------------------------|
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5.19 RS103, radiated susceptibility, electric field, 2 MHz to 40 GHz.

5.19.1 RS103 applicability.

This requirement is applicable to equipment and subsystem enclosures and all interconnecting cables. The requirement is applicable as follows:

- | | |
|---------------------|--|
| a. 2 MHz to 30 MHz | Army ships; Army aircraft, including flight line; Navy (except aircraft); and optional* for all others |
| b. 30 MHz to 1 GHz | all |
| c. 1 GHz to 18 GHz | all |
| d. 18 GHz to 40 GHz | optional* for all |

*Required only if specified in the procurement specification

The requirement at the tuned frequency of an antenna-connected receiver is 20 dB above the RE102 limit associated with the particular platform application.

5.19.2 RS103 limit.

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to the radiated electric fields listed in Table VII and modulated as specified below. Up to 30 MHz, the requirement shall be met for vertically polarized fields. Above 30 MHz, the requirement shall be met for both horizontally and vertically polarized fields. Circular polarized fields are not acceptable.

5.19.3 RS103 test procedures.

5.19.3.1 Purpose.

This test procedure is used to verify the ability of the EUT and associated cabling to withstand electric fields.

5.19.3.2 Test Equipment.

The test equipment shall be as follows:

Table RS103-1. METF RS103 Equipment.

| Item | METF Equipment | Serial # | Calibration ID | Calibration Due Date |
|---|---|----------|----------------|----------------------|
| Signal Generator (<15MHz) | HP 3325B, 0.1mHz-15MHz, or equivalent | | | |
| Signal Generator (>15MHz) | HP83620B or HP8341B or Agilent E8257C or equivalent | | | |
| Signal Generator (pulse modulation source) | HP33120A or equivalent | | | |
| Amplifier (14kHz-220MHz) | AR 150A220 or | | N/A | N/A |

| ED44 / Electromagnetic Environmental Effects (E3) Team | | |
|--|-----------------|------------------------|
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| | | | | |
|-------------------------------------|--|--------|-----|-----|
| | AR 250A250A or equivalent | | | |
| Amplifier (80MHz-1GHz) | AR 100W1000M3 or AR 250W1000A or equivalent | | N/A | N/A |
| Amplifier (1GHz-2.8GHz) | AR 200T1G3A or Logimetrics A610/LS or equivalent | | N/A | N/A |
| Amplifier (2.8GHz-8GHz) | AR 200T2G8AM3 or Logimetrics A600/EH or equivalent | | N/A | N/A |
| Amplifier (8GHz-18GHz) | Logimetrics A600/IJ or equivalent | | N/A | N/A |
| Transmit Antenna (14kHz-30MHz) | AR AT3000 | 304906 | N/A | N/A |
| Transmit Antenna (30MHz-1GHz) | ElectroMetrics EM6917A-1 | 124106 | N/A | N/A |
| Transmit Antenna (1GHz-18GHz) | EMCO 3115 | | N/A | N/A |
| Electric Field Sensor (14kHz-1GHz) | AR FP5000 | | | |
| Electric Field Sensor (80MHz-40GHz) | AR 2080 | | | |
| LISN (Positive Lead) | Solar MIL-STD-461E LISN Model # _____ | | | |
| LISN (Return Lead) | Solar MIL-STD-461E LISN Model # _____ | | | |
| Test Software | | N/A | N/A | N/A |
| | | | | |
| | | | | |

5.19.3.3 Setup.

The test setup shall be as follows:

- a. Maintain a basic test setup for the EUT as shown and described in Figures 1 through 5 and 4.3.8.

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- b. For electric field calibration, electric field sensors are required from 2 MHz to 1 GHz. Either field sensors are also used above 1 GHz for METF RS103 testing.
- c. Configure test equipment as shown in Figure RS103-1.
- d. Calibration. Placement of electric field sensors (see 5.19.3.3b). Position sensors 1 meter from, and directly opposite, the transmit antenna as shown in Figures RS103-2 and RS103-3 and a minimum of 30 cm above the ground plane. Do not place sensors directly at corners or edges of EUT components.
- e. EUT testing.
 - (1) Placement of transmit antennas. Antennas shall be placed 1 meter from the test setup boundary as follows:
 - (a) 2 MHz to 200 MHz
 - 1 Test setup boundaries ≤ 3 meters. Center the antenna between the edges of the test setup boundary. The boundary includes all enclosures of the EUT and the 2 meters of exposed interconnecting and power leads required in 4.3.8.6. Interconnecting leads shorter than 2 meters are acceptable when they represent the actual platform installation.
 - 2 Test setup boundaries > 3 meters. Use multiple antenna positions (N) at spacings as shown in Figure RS103-3. The number of antenna positions (N) shall be determined by dividing the edge-to-edge boundary distance (in meters) by 3 and rounding up to an integer.
 - (b) 200 MHz and above. Multiple antenna positions may be required as shown in Figure RS103-2. Determine the number of antenna positions (N) as follows:
 - 1 For testing from 200 MHz up to 1 GHz, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 35 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.
 - 2 For testing at 1 GHz and above, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 7 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.
 - (2) Maintain the placement of electric field sensors as specified in 5.19.3.3d(1) above.

5.19.3.4. Procedures.

The test procedures shall be as follows:

- a. Turn on the measurement equipment and EUT and allow a sufficient time for stabilization.
- b. Assess the test area for potential RF hazards and take necessary precautionary steps to assure safety of test personnel.

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|--|-----------------|------------------------|
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- c. Calibration. Electric field sensor procedure. Record the amplitude shown on the electric field sensor display unit due to EUT ambient. Reposition the sensor, as necessary, until this level is < 10% of the applicable field strength to be used for testing.
- d. EUT Testing.
 - (1) E-Field sensor procedure.
 - (a) Set the signal source to 1 kHz pulse modulation, 50% duty cycle, and using appropriate amplifier and transmit antenna, establish an electric field at the test start frequency. Gradually increase the electric field level until it reaches the applicable limit.
 - (b) Scan the required frequency ranges in accordance with the rates and durations specified in Table III. Maintain field strength levels in accordance with the applicable limit. Monitor EUT performance for susceptibility effects.
 - (2) If susceptibility is noted, determine the threshold level in accordance with 4.3.10.4.3 and verify that it is above the limit.
 - (3) Perform testing over the required frequency range with the transmit antenna vertically polarized. Repeat the testing above 30 MHz with the transmit antenna horizontally polarized.
 - (4) Repeat 5.19.3.4d for each transmit antenna position required by 5.19.3.3e.

5.19.3.5 Data Presentation.

Data presentation shall be as follows:

- a. Provide graphical or tabular data showing frequency ranges and field strength levels tested.
- b. Provide the correction factors necessary to adjust sensor output readings for equivalent peak detection of modulated waveforms.
- c. Provide graphs or tables (Table RS103-1) listing any susceptibility thresholds that were determined along with their associated frequencies.
- d. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.

| | | |
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TABLE VII. RS103 limits.

| PLATFORM FREQ. RANGE | | LIMIT LEVEL (VOLTS/METER) | | | | | | | |
|----------------------------|----|--|----------------------|--|--------------------------------------|---|--------------------------|--------|-------|
| | | AIRCRAFT OR (EXTERNAL OR SAFETY CRITICAL) | AIRCRAFT INTERNAL | ALL SHIPS (ABOVE DECKS) AND SUBMARINES (EXTERNAL)* | SHIPS (METALLIC) (BELOW DECKS) | SHIPS (NON- METALLIC) (BELOW DECKS) | SUBMARINES (INTERNAL) | GROUND | SPACE |
| 2 MHz ↓ 30 MHz | A | 200 | 200 | 200 | 10 | 50 | 5 | 50 | 20 |
| | N | 200 | 200 | 200 | 10 | 50 | 5 | 10 | 20 |
| | AF | 200 | 20 | - | - | - | - | 10 | 20 |
| 30 MHz ↓ 1 GHz | A | 200 | 200 | 200 | 10 | 10 | 10 | 50 | 20 |
| | N | 200 | 200 | 200 | 10 | 10 | 10 | 10 | 20 |
| | AF | 200 | 20 | - | - | - | - | 10 | 20 |
| 1 GHz ↓ 18 GHz | A | 200 | 200 | 200 | 10 | 10 | 10 | 50 | 20 |
| | N | 200 | 200 | 200 | 10 | 10 | 10 | 50 | 20 |
| | AF | 200 | 60 | - | - | - | - | 50 | 20 |
| 18 GHz ↓ 40 GHz | A | 200 | 200 | 200 | 10 | 10 | 10 | 50 | 20 |
| | N | 200 | 60 | 200 | 10 | 10 | 10 | 50 | 20 |
| | AF | 200 | 60 | - | - | - | - | 50 | 20 |

KEY: A = Army
N = Navy
AF = Air Force

* For equipment located external to the pressure hull of a submarine but within the superstructure, use SHIPS (METALLIC)(BELOW DECKS)

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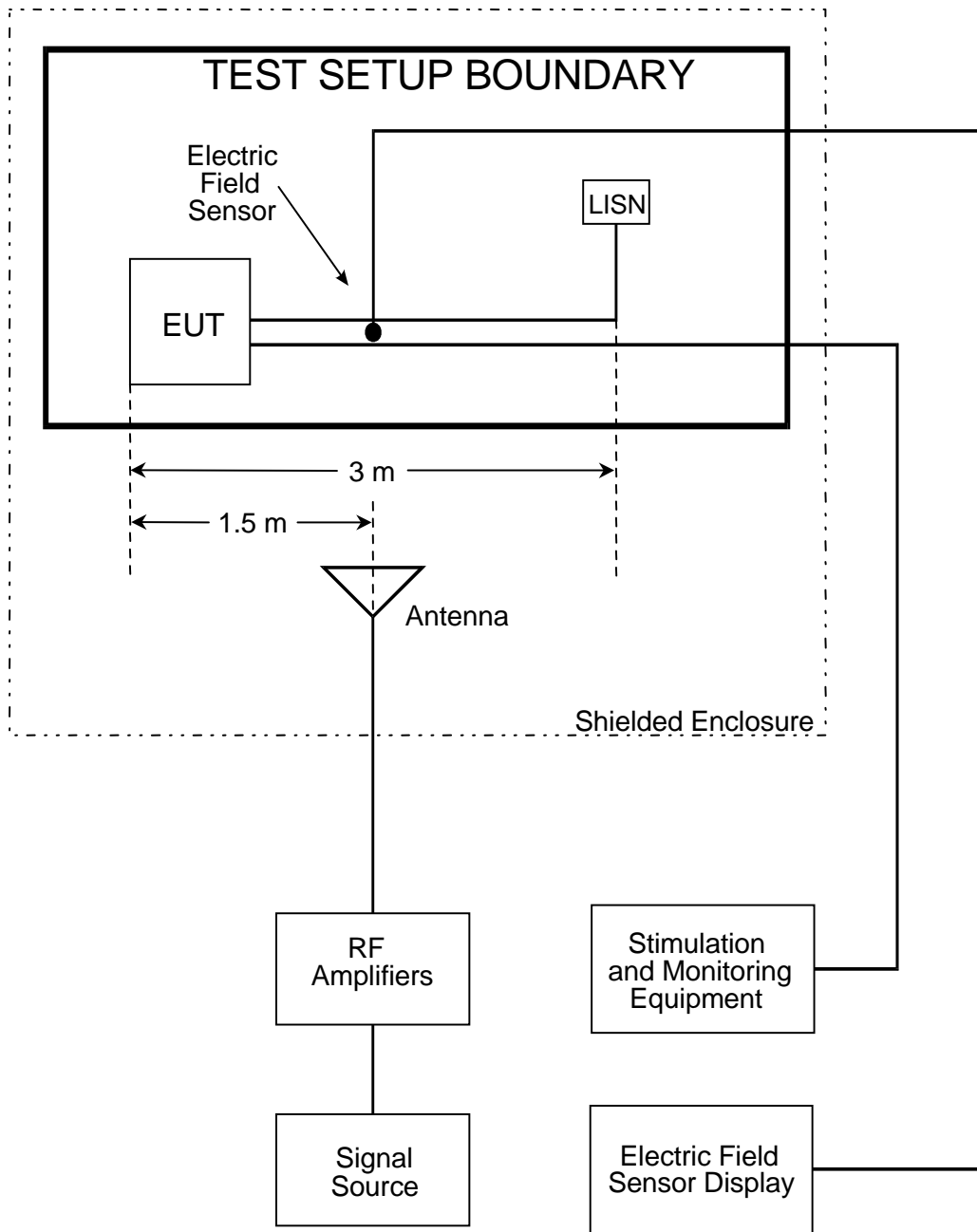


FIGURE RS103-1. Test equipment configuration.

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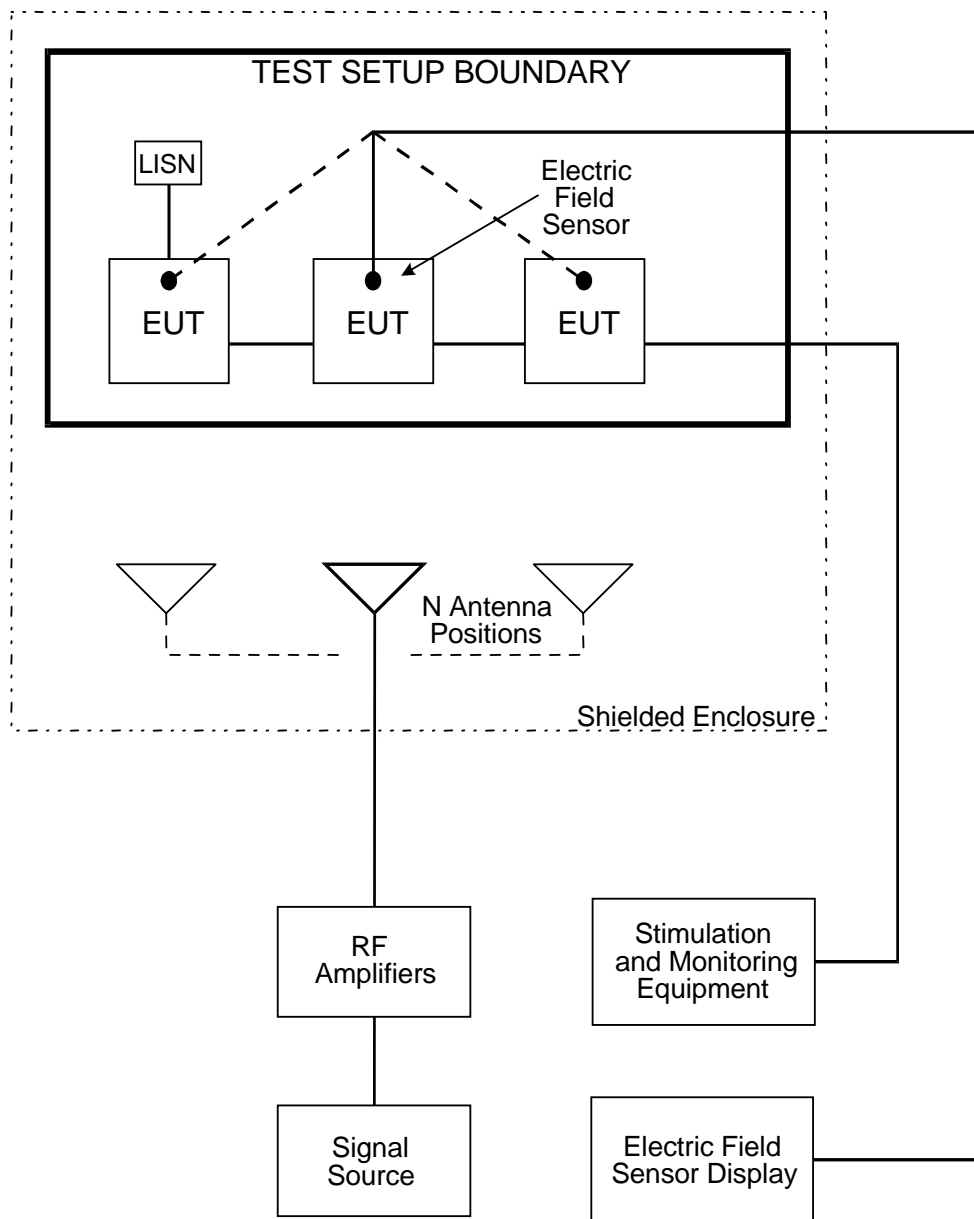


FIGURE RS103-2. Multiple test antenna locations for frequency > 200 MHz.

| | | |
|--|-----------------|------------------------|
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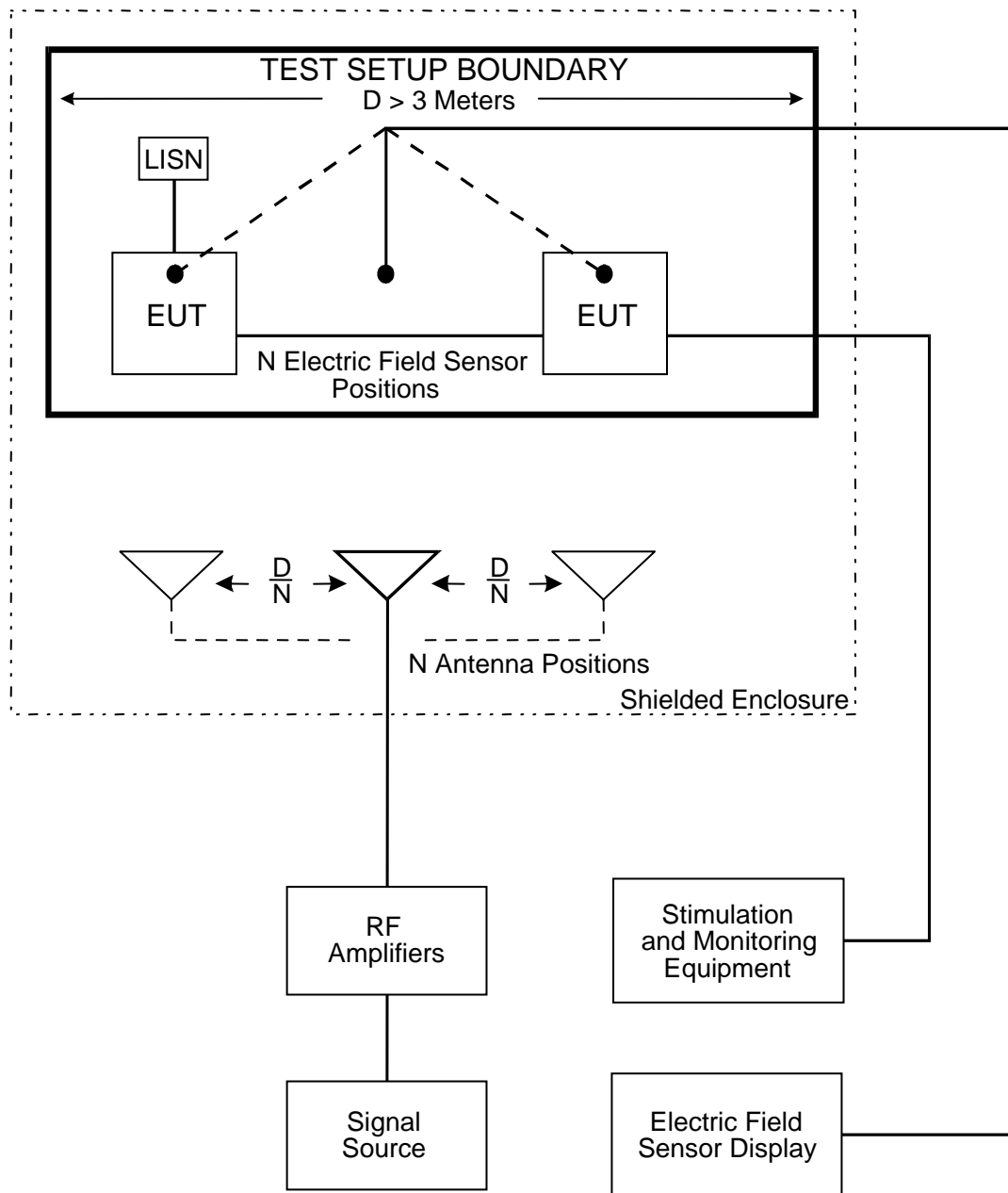


FIGURE RS103-3. Multiple test antenna locations for N positions, $D > 3$ meters.

| | | |
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EUT: _____

| Frequency | Observed Effect (s) | Threshold Level |
|-----------|---------------------|-----------------|
| | | |
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Table RS103-1. RS103 Test Results

